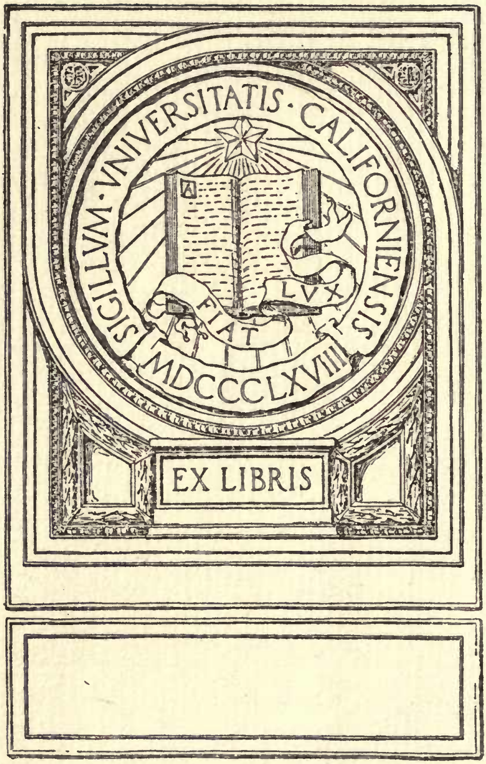

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CONDENSED DESCRIPTION
OF THE
MANUFACTURE OF BEET SUGAR

UNIV. OF
CALIFORNIA

BY

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PREFACE

THIS little book was written in 1903–5, but was not published, and was temporarily laid aside by the author. Recently his attention was called to it again and on re-reading it he was impressed by the fact that very few developments had taken place during this time, and the book could be brought up to date with very few alterations and additions. This has been done.

The author thinks that the brevity and conciseness with which the main principles of the beet-sugar industry are touched upon and treated may make this little book a welcome edition for superintendents, engineers, and foremen of the beet-sugar industry.

DR. FRANZ MURKE.

April, 1920.

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CHAPTER I

HARVESTING, STORING, AND RECEIVING BEETS

Beets are grown in such widely different localities in the United States that it is utterly impossible to give any prescriptions or suggestions, in regard to harvesting and storing them, that will be applicable under all conditions to all these different localities. California and Colorado, for instance, have such different climates that they are not at all comparable. While in California, with a climate without seasons, the harvesting can be so regulated that the factory gets a steady supply throughout the campaign, keeping only a comparatively small amount of stored beets on hand for cases of emergency such as rain, etc.; in Colorado the possibility of losing beets by frost in the ground makes it necessary to have all the beets harvested around the middle of November. Planting of the beets is allowed by the Colorado climate in the beginning of April and they ripen at the end of September, leaving only a short time for the farmers to get the beets harvested. The factory has to take all the beets in the early weeks of the campaign, necessitating storing the beets. Small experiments in different factories have demonstrated that the best way to store beets, and the one involving the smallest losses of sugar, is to silo them in small heaps and cover them with earth. The silos tried here were about 8 feet at the bottom, 4 feet high and 22 feet long. They were covered with earth and a few ventilation air holes were left at the top. Although this is the best method of storage for preserving the beets and sugar, it is not practicable on account of lack of help. The farmers will seldom agree to keep their beets in this way because it means a good deal of hand labor, so the beets have to be stored in large piles on the factory ground as near as possible to the flumes, preferably on a place which is provided with flumes.

The beets may be piled without danger to a height of from 6 to 8 feet. In storing them in this way, special care should be taken to see that they are clean, and beet leaves should be kept out of these piles as much as possible. The watery leaves heat and rot and start a fermentation which readily spreads to the beets.

Special care is also to be observed at the beginning of the harvest in keeping frozen and immature beets out of these storage piles. In cold weather it is a good precaution to cover the sides of the piles with canvas or mats to prevent the sides from freezing and to avoid leaving a layer of frozen beets inside of the pile when other beets are added.

If beets are stored in this way over flumes, the water of the working flumes should be prevented from backing up under the beets. The water, coming as a rule from the tail-tank of the condensers, is warm and steaming and when under a beet pile is liable to start fermentation. Beets which are immature or which have been frozen must be kept out of the main storage pile as mentioned, and should be put on flumes reserved for this purpose and worked up in the factory as soon as possible. It should be borne in mind that the tight cemented bins and sheds which are largely in use in this country are very bad storage places, and the different bins in the sheds ought to be worked through in rotation. If, notwithstanding all precautions, beets stored over flumes should show some heating, which is shown by steam escaping from the beets, the nearest flume should be started, so as to get as quickly as possible to the point of fermentation; if there are no flumes under the pile which has started to ferment, opening the steaming places to the air is the only means of stopping further fermentation. Great care is required to prevent flume water from entering other flumes than that being worked.

The beets received at the factory and at the dumping-stations are generally sampled and tared, the samples being sent to the factory beet laboratory and tested. Of these operations the sampling of the beets is the most difficult. It is not advisable to take a sample from the top of a wagon because, in hauling the beets from the field to the point of unloading, a good deal of the loose earth is shaken down to the lower part of the wagon. In cases where the beets are emptied from a dump into cars, a basket hung on a swinging crane underneath the apron of the dump is swung into the stream of falling beets and filled, the contents of the basket being used as the sample. Where the wagons are dumped directly into the flumes, a basket is held under the side board of the wagon to catch the best average sample possible. In case beets are shoveled, a number of samples have to be taken and mixed together to insure as good an average as possible. The sample is weighed and cleaned, and then topped if the topping has not been done properly. The topping is generally done at the lower leaf marks. It may be mentioned that if these tare samples are retopped during taring and used for the polarization, the latter will be a little higher than the polarization of the whole load.

CHAPTER II

FLUMING, WEIGHING, AND WASHING OF BEETS

For the transportation of the beets from the sheds to the factory flumes are now used almost everywhere. They are in the center of the sheds and are generally covered with boards on which the beets are stored. The flumes are 300 to 500 mm. wide, at least 600 to 700 mm. deep, and have a slope of about 10 mm. to 1 meter in the straight portion and about 12 mm. in the curves.

The water for the flumes is generally taken from the tail-tank of the condensers. The pipe lines from this tank to the manifold in front of the flumes should be looked over after each campaign, because a large amount of carbonate of lime is often deposited if the water used in the condensers is rich in lime salts. The ammonia and carbon dioxide in the vapors from the juice, coming in contact with the water, which contains lime, naturally precipitates the lime carbonate, and this substance gradually stops up the pipe lines through which the water runs.

The water coming from this source is naturally warm—40 to 45° C. As already noted, this water ought to be kept from backing under the unworked flumes. For the working flume this heat is not objectionable, but, on the contrary, helps to loosen up the clayey soil which adheres to the beets. The sugar losses in the flume water are small, but some diffusion of sugar takes place, not so much with whole beets as where many bruised and broken beets are flumed.

The beet silos over the flumes should always be started at the lower ends, the end near the factory. Starting to flume at both ends of the silo is risky, because in this way a wooden flume cover might easily get into the water and be caught under the beet pile, where it might cause stoppage and blocking of the whole flume.

Stone-catchers are often built in the main flume a short distance from the entrance to the house. There are generally two of them so that they can be alternately cut out of service and cleaned. Trash-catchers are used to catch beet leaves, wood, and other material floating on the surface. A piece of wood with projecting nails on the lower surface does good service; or light iron hooks, which can be taken out and cleaned, are used. Nowadays automatic trash-catchers, built on the same principle, are widely used.

From the flumes the beets are generally flooded into elevating devices. Elevators, beet wheels or screws lift the beets into washing machines, the water being sometimes lifted in the same way. A beet screw lifting the water must fit pretty closely to the trough and make about sixty revolutions a minute. The water should not be lifted into the washing machine, but only to a height sufficient to obtain a fall to the sewer or settling tanks.

Clean water should be introduced into the washing machine; and here again it is well to use water from the condenser tail-tank, as this is warmer than the main water supply. Warm water is especially necessary to thaw off the earth from frozen beets.

The most commonly used beet-washing machines are those with open troughs of perforated iron, round at the bottom and set in a closed cover with a revolving shaft in the center on which wooden arms are fastened, which are generally arranged in a spiral to move the beets from one end of the washer to the other. From here the beets are thrown out into a beet elevator.

Good stone-catchers in the beet-washer are of importance, and they are most effective if the water for the washing is introduced into the washer from underneath the perforated sheets, so that it has to flow upward, leaving the heavy stones at the bottom of the stone-catcher. The stone-catchers have to be cleaned often—once a shift or once a day. The cleaner the beets are the better it is for the knives and the less they have to be changed, as sand and dirt dull them in a very short time.

From the beet-washers the beets are taken by an elevator to the top of the house and emptied, as a rule, into the beet scales. Weighing of the beets gives the only reliable figure for the sugar introduced, and is indispensable for a beet house which attaches any importance to the chemical control. The most reliable automatic scale is the Chronos scale, built by the Hennefer Maschinenfabrik, Henneff a. d. Sieg. This scale is used almost exclusively, on account of its reliability, but nevertheless it is essential to check the scale from time to time, and provisions ought to be made for obtaining check tests without too much inconvenience and without delaying the work of the house. A movable apron by means of which the beets may be diverted to an outside scale gives little trouble, and the more conveniently this check can be made, the oftener it will be made.

The scales empty the beets into the cutters.

CHAPTER III

CUTTING OF THE BEETS

THE weighed beets are cut in beet-slicing machines, of which there are different forms in use. The most commonly used machine, however, consists of a rotating horizontal disk, in which the holes for the knife boxes are so arranged that the edges of the knives coincide with the radii of the disk. Over the disks there is a cylinder into which the beets are emptied from the scales. The cylinder has a central conical hood covering the upper box of the shaft and connected by a triangular hood with the outside cylinder—the triangular hood permitting the knives to be changed. About $\frac{1}{2}$-inch above the knives there are several ribs which can be lowered and raised and which keep the beets in their places and prevent them from rolling. The beets are pressed down by their own weight against the rotating knives and cut into "cossettes" of different shape and thickness.

The original beet-cutters of this style had a smaller diameter and revolved more rapidly—1000 to 1500 mm. diameter with about one hundred revolutions.

More recently these machines have been built larger in diameter and their speed has been reduced to about forty revolutions. The general opinion is that larger machines with fewer revolutions give better cossettes. The height of the cylinder containing the beets is about 2000 mm., to insure a pressure of the beets against the knives. It is detrimental to good cossettes to run the cutters almost empty.

About 1 foot above the disk there are holes in the mantle of the machine, through which iron pins can be pushed in case a stone or piece of iron gets into the machine. If a foreign body gets into the cutter it makes a rattling sound. The machine must then be stopped immediately, the pins inserted and the cutter cleaned through doors which are generally just behind the iron ribs mentioned above. These are the places where stones are generally found.

The knives are, as a rule, 140 mm. wide, and in smaller machines there are two knives in one box, in larger machines three. The number of partitions in one knife of 140-mm. width regulates the fineness of the cosettes, and varies from twenty to thirty-five with much variety in the construction of the knives. Single knives and double knives are used, the latter being really two knives, one behind the other, in the same box. Of the single knives, the rib-roof knives (Dachrippenmesser) are the most commonly used, and they have many advantages, especially if their ribs are very long. With long ribs, the knives can be put quite far from the guide plate of the box without fear that the cossettes will not be cut clear through, thus avoiding hand or comb-like pieces, which are objectionable in the diffusion process. The main purpose of not having the knives too near the guide plate is to leave some space through which small stones and sand can pass without dulling the edges of the knives. Straw and roots pass more easily when the knife is set farther from the guide plate than they would through a narrower space.

The same purpose is accomplished by guide plates which are provided with channels. Such guide plates are made by Binkley, Kilby, and others, and do good service where beets are mixed with much straw, alfalfa roots or gravel. A long rib also enables the knife filer to set the knife higher, thus avoiding combs, and to obtain coarser cossettes whenever these are desirable, as in the case of fermented and soft material.

In sharpening a knife the greatest care has to be taken that the point of the "roof" is sharp, and the dull knife must be ground back until there is no rounding of the points. A perfectly sharp knife with round arches instead of points does not give good cosettes.

The rib-roof knife is set at a very small angle to the guide plate of the knife box, allowing a free and smooth passage of the cossettes. Herein may be seen the superiority of the rib-roof knife over the double knives in use. These latter consist of a front knife, cutting triangular cossettes out of the beet, and a straight knife behind, cutting off the triangular projections left by the first knife, and leaving the surface smooth. The front knife is set at a much steeper angle than the rib-roof knife, which causes breaking of the cossettes. On the other hand the double-knives are more easily sharpened. Good diffusion work is dependent on the keenness of the knives and the consequent condition of the cossettes.

Another form of beet cutter is the drum cutter, or Maguin cutter. The knives in this case are inserted in a drum revolving around a horizontal axis. The cutting is done inside of the drum and the beets are introduced into this drum in a wedge-shaped space, so that a pressure of the beets against the knives is obtained. The knives are built on the same principle (rib-roof knives).

CHAPTER IV

THE DIFFUSION PROCESS

From the beet cutters the cossettes generally fall on a cossette conveyor, usually a rubber or gutta percha belt in the case of a long battery, or a movable metal trough or spout in the case of a circular battery. They are then transported to the different diffusion cells.

The two principal types of diffusion batteries are the circular and the straight battery; the former has the advantage of having the different valves closer together; but it cannot be enlarged as easily as a straight battery.

The contents of the diffusion cells vary from 30 to 80 HL and their number varies from eight to fourteen in a battery. The size of the cells, of course, varies with the capacity of the house. To give some idea of the proportion of a battery as to capacity, it is only necessary to state that a battery of fourteen cells of 70 HL capacity each, with chains inside of the battery cells, is considered necessary for a daily capacity of 1100 long tons. Such a battery, working over twelve cells, has an amount of 44 to 46 tons of cosettes in circulation and has to draw eleven to twelve cells per hour, which means that about 45 tons of beets have to pass through the battery per hour.

There are two different types of cells which are most commonly used. One type consists of cylindrical cells with upper filling door and low side-discharge door, with a flat double bottom with a slight inclination toward the door, the upper bottom being a perforated sieve on which the cossettes rest. The juice which enters the cell at the top neck passes downward through the cossettes in the cell and out through the sieves. From under the sieves it goes through a pipe to the top of the next cell.

Opposite the discharge door there is a water pipe for cleaning the cell after the diffusion is finished. If the mouth of this water pipe is a little smaller than the area of the pipe and is flattened out so as to spread the water over the bottom of the cell, the latter can be emptied more quickly and with the use of less water.

Such a battery requires a man to empty the cells at the ground floor. With the side doors this work is rather sloppy and wet; the battery cell with a central bottom door is much cleaner in that respct.

The sieves in this case are on the bottom and in the lower conical part of the cell.

Since these doors are most effective when they are of very large diameter, they are often connected with hydraulic closing installations operated from above. Nevertheless, mechanical help is sometimes required to empty a cell. An improperly closed cell or a leakage of the gaskets may cause considerable loss of sugar, and it would not seem a wise economy to leave the lower doors of the cells without regular attendance.

The height of a diffusion cell is generally between 1.15 to 1.5 times the diameter.

The diffusion battery is heated either by direct injection of live steam into the pipe-line leading from the bottom of one cell to the top of the next, or by calorisators which are attached to each cell and through which the juice has to pass. The calorisators are heated by live steam, exhaust steam, or vapor from the first evaporator. Even the second evaporator may be utilized for this purpose if the heating surface is large enough and the temperature of the second body is near 100° C. It is surprising that there is no apparent dilution of the juice by injection of live steam and that it is possible to draw just as concentrated a juice from a battery with live steam injection as from a battery with calorisators. However, if the calorisators are heated by vapor from the evaporators, the steam is used in a double or triple effect, which means economy of coal. We refer in this connection to a rough calculation of the steam consumption of a beet factory in the chapter on evaporators.

If heaters are used connected with the battery cells they must be provided with sample cocks at the steam chamber, and the condensed water of these heaters should be carefully watched. It must be borne in mind that during each round of the battery, the temperature of the heaters fluctuates from a few degrees above zero to 80° C. and higher. This continuous fluctuation of the temperature makes the metal of the heating tubes crystalline after they have been in use for several campaigns, and breaks and leakage of the tubes are a common occurrence. For this reason the outlets of the condensed water from these calorisators ought to be provided with check valves so that the water of one heater cannot go over into another, which would make difficult the discovery of a leaking heater.

Each diffusion cell has to be provided with thermometers, which are so placed, in case of live steam injection, that they cannot come into direct contact with the steam. At the top of the cell there are air valves to let the air and gases out of the cell, if it is necessary.

Good service can be obtained from pressure gauges connected with each cell of the battery. Such pressure gauges show the gradual decrease of the pressure in the different cells, from the first cell, which is generally connected with the main water tank of the factory or with a special pump, and has a pressure of between one and three atmospheres, down to the last cell with very little pressure. (During the maishing of the next cell syphoning sometimes produces a vacuum.)

In case a cell in the circle of the battery is packed with bad cossettes, the decrease of pressure between this cell and the following one will be considerable, and the place where the trouble is can easily be detected. The practical gain of this knowledge is not so great, however, as it might seem, because in such cases there is only one remedy, which is, waiting until that cell is cut out. Shortening of the battery helps a little, in so far as the bad cell is cut out one or two cells sooner.

The water pipe of the diffusion battery is usually connected with a warm-water pipe to make possible the use of the warm water from the condensers. This water is pumped to a warm-water tank and from there connected with the battery, or the water is pumped through a reversed U stand-pipe with valves at different heights, an arrangement which provides for different pressures. Care should be taken that in using warm water the circulation of the battery does not suffer. A temperature near 50° C. may be considered a proper temperature and, under general circumstances, will not soften the pulp nor slow down the circulation.

A group of cells, nine to twelve in number, are connected so as to form a working unit. If the battery is a short one, less than nine cells may form a group. The water enters the last cell containing almost exhausted pulp. The water, being heated on its way, flows from the bottom of one cell to the top of the next one, gradually growing richer in sugar and other extracted substances until it comes to the first cell, where it passes through fresh cossettes out to the measuring tank. Here a certain amount of juice between 110 to 140 per cent on beets is drawn off, and after that the current of the juice is changed to the next cell, which in the meantime has been filled with fresh cosettes. The juice enters this cell at the bottom, gradually filling the whole cell and driving out the air. As soon as the cell is filled the current of the juice in this cell is reversed and another measuring tank of juice is drawn off. At the same time the water pressure is changed from the last cell to the next and the cell which was the last, and now contains the exhausted pulp, is emptied into a flume below the battery. The pulp is generally floated on this flume to an elevator or a pump, some distance away.

The sugar is taken out of the cossettes by an osmotic process. The sugar solution inside of the organic beet cell diffuses into the thinner solution outside of the cell. By the high temperature, between 60 and 85° C., the protoplasmic membrane of the plant cell is killed and becomes penetrable for the sugar; but it becomes penetrable for other substances also, especially so for the soluble salts contained in the beets.

A good many albuminous substances are diffused into the juice and some substances which are not in solution in the beets are dissolved in contact with hot water and thinner sugar solutions.

Good work in the diffusion process aims to extract as much of the sugar as possible and to obtain clean concentrated juices with as few impurities as possible. The different substances which go into the diffusion juice may be divided into three groups.

First Group: Substances which diffuse more easily than sugar.

Second Group: Sugar and substances which diffuse as easily as sugar.

Third Group: Substances which diffuse more slowly than sugar and partly dissolve before diffusing.

From this point of view, the theory might be deduced that too thin juices have a larger proportion of impurities than more concentrated juices, and that, on the other hand, if the concentration were carried too far impurities might be dissolved after the diffusion of the sugar had ceased, on account of the small difference in concentration inside and outside of the plant cell.

Good battery work results in an increase of the purity of the diffusion juice, over the purity of the pressed juice, of one to one and a half points. This, however, is not always obtainable, and depends largely on the nature of the impurities. The obtainable increase in purity varies with different seasons with beets from different soils, etc.

With good, fresh, and healthy beets the extraction might be carried down to .17 per cent sugar in the pulp and .08 per cent sugar in the pulp wash water, or from .25 to .30 in the two together. The pulp, when it comes from the battery cells, roughly drained from the adhering water, weighs very little less than the cossettes going to the battery; and the pulp water surrounding the pulp in the battery cell amounts approximately to the same weight, so that the addition of these two loss figures represents very closely the loss in the battery, and, subtracted from the sugar in cossettes, leaves the yield of sugar in the diffusion battery.

As to the temperatures in the battery, it should be remarked that there is a higher limit where the cossettes become soft, pack down on the sieves, and slow down the circulation. This is the worst thing that can happen to a diffusion battery, because in consequence of the bad circulation the cosettes stand for a long time in contact with the juice at a high temperature. This gives impurer juice, dissolves pectin and other substances, besides retarding the work of the whole house. With fresh and well-shaped cossettes, 85° C., even 90° C. may be considered as a maximum. It is advisable to keep a little below the limit of the highest temperature, because some little irregularities are not be be avoided and when near the limit may become detrimental; and it might be wiser to keep one additional cell in operation, with a little lower temperature, but to keep the circulation at the very best.

The old practical rule, to work the juices as quickly as possible, not only gives the best result in tonnage, but also the best and healthiest juices. The time occupied by the diffusion depends upon the method of working, the temperatures used and the number of cells in the battery. With a shorter battery and a higher temperature in the different cells, the diffusion may be carried on as well as with a longer and cooler battery; and the danger of cooking the cossettes is smaller in a short battery than in a longer one of the same temperature. The time necessary for hot work in the battery may vary from one to one-and-one-half hours, for colder work from one hour and a half to two hours.

It is considered advisable to keep the highest temperature as near the head of the battery as possible, because a high temperature is detrimental to the activity of bacterial life, and the sooner the bacteria are killed the smaller will be the sugar losses. Furthermore, by high temperature in the first cell, some of the albuminous substances may be precipitated and kept in the cossettes instead of going into the diffusion juice.

Whenever fermented or soft material is to be worked, it is advisable to reduce the temperature in the battery quickly. Such material is more liable to become soft, and the first result will be impaired circulation with all the objectionable consequences thereof. In such cases it will be an advantage to have chains inside of the cells to relieve the pressure of the cossettes against the sieves.

It is evident that fine and even cossettes make easier diffusion work than coarse ones; but on the other hand they are much more liable to become soft and mushy. It is therefore advisable as soon as material of dubious character (fermented or frozen beets) is to be worked, that the thickness of the cossettes be increased.

When beets are only partially frozen and are mixed with healthy beets, they do not offer such serious objections as are generally credited to frozen beets. The frost kills organic cells and the diffusion process seems to go on as well at a lower temperature with bigger cossettes. This remark of course, applies only to slightly frozen beets. Thoroughly frozen beets are hard to work, the common knives are not able to cut them. In some cases it is necessary to use finger knives which cut very big and irregular cossettes, while in some extreme cases the cossettes in the cell freeze together in bunches which the juice does not penetrate; and even after a whole circulation of the battery, after the cossettes have been treated from one to two hours with warm juice, pieces of ice may come out of the cells containing cossettes not changed at all. A low temperature in the battery is to be recommended in the case of such beets.

The worst kind of beets are those which have been frozen and afterward thawed. Beets which have been killed by frost undergo rapid fermentation, if they do not stay in a frozen condition but are thawed out later. Such beets become mushy and soft and no longer yield clean-cut cossettes. The cossettes from such beets pack together and clog up the sieves. In such cases chains are of the utmost importance. The lowest possible temperatures should be used. Cold water should be used at the tail end of the battery instead of the condenser water and the sugar content of the pulp should be carried higher. The more rapidly beets of that character are worked, the smaller will be the losses.

Another irregularity which may occur is the development of gas in the cells, owing to the influence of bacteria. This occurs less often with high temperatures and short duration of the process than with cooler and longer work in the battery, the higher temperature being unfavorable to the bacteria. These gases are inflammable and when mixed with air are explosive. Therefore, in such cases open lights have to be kept away from the empty cells. If such fermentation has once started in the battery the circulation is perceptibly slackened and this in turn increases the fermentation. In such cases, it may be advisable to sweeten off the battery and start in again with fresh cossettes. In some cases lime and soda ash have been added, and it is claimed that the result was good.

Sometimes air gathers in the necks of the cells, retarding the circulation, and has to be taken out through the air cocks on top of the cells.

Beets which have gone to seed are woody and hard to cut. The knives have to be changed often and had better be set a little higher and further apart from the guide plates, provided knives with high ribs are at hand.

The juice should not be allowed to stand for a long time in the battery; and the practice of not sweetening off the battery on a clean-up day, but letting some cells stand, to start again with fresh beets, ought not to be allowed. There is nothing to be gained by this method, because in any case the exhausted steam goes out to the roof at that time. On the contrary, in cases of longer interruptions at the stations before the battery, the diffusion battery should be sweetened off or at least a measuring tank should be sent over every half hour to keep the battery in a slow motion.

One mistake which frequently occurs at the battery is that a wrong water or juice-valve is left partly open or that something gets under the seat of this valve. Such a mistake can be detected in the density of the diffusion juice much sooner than in the sugar content of the pulp. It is therefore advisable to measure the temperature and the density of each measuring tank and have these figures recorded in a little book by the boy who attends the measuring tanks. As soon as a sudden drop in the density of the diffusion juice is noticed, or as soon as the thermometers of the cells show a sudden drop, all the water-valves and the juice-valves of the battery and the water wash-out valves must be gone over till the leaky valve is found.

In order to start the diffusion battery, five to seven cells are filled with hot water, which is sent from one cell through the others in the same way as in the regular work, with all the steam valves of these cells open, till the water in the first cells has reached a temperature of about 75° C. Then, starting the beet work, a number of cells, about four to six, are maished without drawing off any juice to the measuring tank. After that the regular work is taken up.

In sweetening off the battery two measuring cells are drawn off for each cell to be cut out at the end of the battery, until five or six cells are left in the battery; measuring tanks are drawn off from these till the last juice shows about 0.75 per cent to 1.0 per cent of sugar. Then these cells are dumped one after the other. It is better not to shorten down the battery too much, because it is easier to keep the right temperature with a cell or two more.

CHAPTER V

BEET PULP

THE exhausted pulp is generally dumped into pulp flumes. In order to do this, the pressure of the cell has to be relieved, which can be done through the air cock on top of the cell or through valves that are attached to the lower end of the pipes leading from one cell to the next. In the latter case, a small vacuum can be obtained. These valves have to be watched carefully so that they are not left open; otherwise heavy losses of sugar might take place here. Some factories arrange these cocks or valves in such a way that it is not possible to close the cell before the valves are closed. After the pressure of the cell is relieved the bottom door is opened and at the same time the upper door is lifted so that the whole contents of the cell are dumped into the flume.

The flumes are large and wide enough to receive the contents of several cells and generally have a slope of 35 to 50 mm. per meter. The water in the cells, which amounts to a little more than the pulp itself, is often sufficient to flume the pulp. In other cases some additional water is used to flume the pulp toward the elevating device at the end of the flume. In such cases some of the water pressed off the pulp is returned to the upper end of the flumes to avoid wasting too much fresh water.

The elevating device for the pulp lifts either the pulp and the water or the pulp alone. The most commonly used lifting devices for pulp are elevators with closed or perforated buckets, or screws similar to the beet-screws with perforated troughs at the lower end of the screw, or centrifugal pumps. In cases of elevators with perforated buckets, sieves are provided, through which the pulp-water drains off and the returning buckets have to be arranged in such a way as to scrape the sieves free. When pulp and water are lifted together, the pulp-water can be used with some additional water to flume the pulp out to the pulp silo. In some factories the pulp passes through presses which take part of the water out and then the pulp is dragged out to the silo.

In all cases where it is possible to keep the pulp-water separate from the bulk of the sewer-water this should be done, because pulp-water is the most objectionable water of a beet-sugar factory, with the exception of the Steffen, and osmose waste water. It contains a small amount of sugar and other organic and inorganic substances in solution, and in addition to that, it carries a considerable amount of pulp particles which pass through the sieves. This water is directly poisonous to fish, etc., and especially so after it has started to ferment. In many factories, where the diffusion water can be separated and the lime-mud flumed out to lime-mud settling-ponds, this water may be used to flume the lime-mud. In this way a good deal of the suspended organic matter is carried down with the lime-mud and the water partly purifies itself. In other cases the pulp-water is used to flume the ashes from the boiler house to settling ponds, with some cleaning effect on the water.

The pulp presses generally used in this country are not very efficient; they consist mostly of a perforated cone with a shaft inside and arms set in a spiral. These presses do not give a very dry product. About 10 per cent of dry substance may be considered average work for them. Good pulp presses press the pulp as dry as to contain about 16 per cent of dry substance. Such high dryness of the pressed pulp is especially desirable for factories with pulp dryers. It is easy to see that, of a pulp with 16 per cent of dry substance, 5.63 parts are necessary to make 1 part of dried pulp with 90 per cent dry substance, whereas 9 parts of pulp with 10 per cent of dry substance are necessary for the same amount of dried pulp. That means, in one case, 4.6 parts of water are to be evaporated; in the other case 8.0 parts on 1 part of dried pulp. In most factories with pulp dryers, pulp and molasses are mixed and dried together, the result being an excellent stock food. There are, however, only a few factories with pulp dryers in this country; and it is very questionable whether a pulp dryer is a paying proposition, in a country where hay and other foods are so abundant.

In this country it is now customary to feed the pulp wet, in the immediate vicinity of the factory, keeping the livestock in corrals near the place of production. This obviates the necessity of pressing the pulp very dry to make it fit for transportation. The food value of the pulp consists partly in the addition of direct nourishment, partly in the influence the pulp has on other food, making the latter more digestible. Practical experiments have shown beyond a doubt the value of beet pulp in fattening; and the farmers, formerly so opposed to feeding pulp that the latter was a most undesirable by-product of the factory, have now so thoroughly convinced themselves of the value of pulp for feeding stock that many factories cannot meet the demand. Pulp in a fermented state is generally preferred by cattle and sheep. However, we shall go no farther into this agricultural speculation, which leads a little too far away from the subject of this book, but shall close this chapter with the remark that the approximate amount of pressed pulp of 11 to 15 per cent dry substance is between 45 and 55 per cent on beets. In fermentation, the pulp loses about one-third of its weight. Of dried pulp, about 5.5 per cent of beets is the usual yield.

CHAPTER VI

DIFFUSION JUICE

The diffusion juice coming from the battery has a density of 12 to 16 Brix with 10 to 13 per cent sugar; it has a light gray color, but darkens very quickly on coming into contact with air. The juice carries small particles of pulp in suspension; and it is essential to clean and screen it, before it goes to the carbonation, because the lime, acting on the pulp, forms slimy substances which hinder the filtration in the presses. With 2.5 or 3 per cent of lime, however, this influence might not be so noticeable. The pulp-catchers in use are generally cylindrical sieves rotating against brushes or springs which keep the sieves clean. The pulp-catchers have to be cleaned often. One cell is usually connected with the pulp-catcher, and every time this particular cell is half filled with fresh cossettes, the return valve of the pulp-catcher is opened and a stream of diffusion juice passes the pulp-catcher in reversed current, flushing the small pulp particles into this cell. It is essential to wait until this cell is half filled with fresh cossettes, because, if the small particles of pulp come in contact with the sieves, the sieves will be partly stopped and the circulation in the battery will suffer.

In most of the factories of this country the pulp-catchers are replaced by a simple screening device in the measuring tanks. A perforated sheet is generally installed in the measuring tank in such a way as to separate the inlet and outlet valves. This device is crude and only catches the larger pieces, allowing the very small pulp particles to pass into the carbonation; but these sieves are easily cleaned and are open to inspection.

The diffusion juice contains in solution all the substances which are extracted from the beets. Besides the sugar these consist of albuminous substances, other nitrogen-carrying organic substances like betain, etc., invert sugar, and perhaps other reducing substances, oxalic acid, citric acid, etc., and inorganic substances such as phosphoric acid, sulphuric acid, potash salts, sodium salts, chlorine, lime salts, magnesium salts, etc. The non-sugar substances of the diffusion juice are only partly known. All diffusion juices are acid, but to such a slight degree that, as a rule, heating of the diffusion juice does not noticeably increase the invert sugar, unless the temperature goes too high or extends over too long a period.

Furthermore, a quick working of the diffusion juice is most essential on account of the presence of many different kinds of bacteria. Many bacteria of the beets, and of the soil adhering to the beets, go into the diffusion juice, and, as the temperature of this juice is usually favorable to their development, they prove very destructive to the sugar. The temperature of the diffusion juice varies considerably according to the work in the battery, from almost zero to over 40°, but is generally between 25 and 35° C. It is therefore essential to heat the juice quickly to a temperature of over 60° C. at which temperature many bacteria are killed, or at least rendered inactive. The more quickly this heating is done the better; and the smaller the quantity of diffusion juice on the way from the battery to the carbonation the smaller are the chances of destruction of sugar.

From the measuring tanks the juice is generally pumped through heaters to the carbonation. Formerly open heaters were used for this purpose, but recently closed heaters have replaced them. The superiority of the closed heaters over the old open heaters is to be seen in the fact that closed heaters do not expose the juice to the open air, which may increase the number of bacteria, and that they contain much less juice. The juice is pumped through groups of heating pipes at a high velocity and therefore heats more rapidly.

The incrustation in these heaters is appreciably less than in the open heaters, due to the higher velocity of the juice.

The closed heaters generally have a cylindrical or trunk-like form with heating pipes so arranged between the two headers that the juice has to pass and return several times through different groups of heating pipes. The heat around the tubes is best produced by vapor from the evaporators, and the most economical method of arrangement is to divide these heaters into two groups, of which the first group is interposed in the vapor line between the last evaporator and the condensers, while the second group is heated by vapor from the first or second body of the evaporators. These latter heaters have to have ammonia pipes from the top of the heater to the juice chamber of the next body to insure a free admission of the vapor.

The condensed water of the heaters has to be watched carefully because on account of the conditions in the evaporators, there is a higher pressure in the juice chamber than in the steam chamber. The condensed water of the heaters heated by vapor from the last body, is taken away either by a pump or by a closed tank underneath the heater, which has to be emptied when it is nearly filled. The second group of heaters ought to be arranged in such a way that they can be heated either with vapor or with exhaust steam, because in the beginning of the work, after a clean-up or at the start of the campaign, there is no vapor at hand and the strict observation of the right temperatures is certainly of no less importance at the start of the work.

The heating tubes of all the heaters become dirty after a while and have to be cleaned. In open heaters this cleaning is easily done during the work with brushes and other mechanical devices; closed heaters have to be alternately cut out and cleaned with brushes. It is easy to remove the incrustation of diffusion juices with a strong solution of sodium hydrate; and if proper arrangements are made for this purpose, all hand labor can be avoided.

The heater station should be big enough to heat the juice up to 80 or 85° C. on its way to the carbonation. The addition of milk of lime or saccharate will then cool the mixture down to about 75 to 80° C., which is the most desirable temperature for the carbonation. Repeated attempts have been made to add the lime before heating the juice; but serious difficulties have been experienced in sweetening off the presses on account of the dilution of a considerable amount of lime in the colder juices and the precipitation of hot trisaccharate during the following heating. This hot trisaccharate is harder to carbonate.

CHAPTER VII

FIRST CARBONATION

THE heated diffusion juice at a temperature of between 70 and 85° C. is treated with lime. For this purpose many factories have separate defecation stations; in other factories, and this is the common practice in this country, the lime is added in the carbonation tanks, in the form of hydrate, as a milk of lime of about 20° Bé., or as burned lime from the kilns, the slacking being done in the juice itself. In this latter case the direct addition of lime to the carbonation tanks is not practicable, and there must be special tanks for this purpose. The juice in this case has to be in heavy circulation through the lime on account of the danger of burning sugar. In hydrating lime about 150 calories are freed per kilogram, so that there is considerable danger of caramelizing sugar. In factories where dry lime addition is practiced in an imperfect manner the juices are generally of darker color, although it is possible to obtain just as bright juices by this method, if all the lime is covered with juice and this juice is in heavy motion. The advantage of a dry lime addition is that, under some conditions, a little less water is required.

Where milk of lime is added, the sweet water of the filter presses is used to make the milk of lime; but this sweet water is not sufficient, and the difference has to be made up with juice or hot water. However, there are very few, if any, factories in this country, using quick lime addition. Therefore we will not go any further in the description of this method. Furthermore, as there are very few factories in this country which add the milk of lime in separate defecation tanks, we will confine ourselves to the description of the addition of milk of lime in the first carbonation tanks.

Only a small amount of lime is necessary to neutralize the diffusion juice and to precipitate the substances which are precipitable by lime; .5 to .75 per cent would be sufficient to do this work, but the resulting mud would be slimy and could not be readily filtered after carbonation. There are a good many gummy substances, albumin, etc., which do not filter readily, and therefore more lime must be added. Raw sugar factories use 1.5 to 2.5 per cent of lime and white sugar factories 2 to 3 per cent of lime on beets. The best criterion of how much lime is to be given is the condition of the mud in the filter presses. This lime mud has to be solid and hard to insure effective and quick filtration and, as soon as the mud in the filter presses becomes soft and gelatinous, the lime addition ought to be increased, unless the soft condition of the mud is caused by other factors, such as leaky valves, etc.

The lime addition, furthermore, ought to be kept a little above the necessary amount, because the contents of the milk of lime which is sent over from the lime kiln may vary in density. The diffusion juice may also vary in density, so it is advisable to be on the safe side and add a little more lime than is absolutely necessary, if the sizes of the affected stations allow such a proceeding. The purifying effect of the excess lime is practically nothing. It is only a precaution against mistakes and variations in the process. The amount of lime going into solution depends upon the sugar content of the juice and on the temperature. In cold juices a large percentage of lime goes into solution, in warm juices of about 80° C. only .25 to 0.35 per cent of lime is dissolved. The warmer the juice is, the less lime goes into solution; it is therefore a mistake to heat the juice after the lime addition, because the lime which has gone into solution after being heated forms hot trisaccharate which is harder to carbonate.

The effect of the lime addition is a mechanical and chemical one. There are many organic particles suspended in the juice and these are enveloped and carried down by the lime so that they become capable of filtration. The chemical reaction of the lime is complicated. First the lime unites with all the free acids in the diffusion juice and forms insoluble salts with the higher organic acids which have been combined with alkalies. It frees these alkalies and the ammonia, which, together with lime, act on the non-sugar of the juice. Lime decomposes some organic non-sugars and changes their nature; it also destroys the invert sugar which is present in almost all diffusion juices and decomposes the amide, amine and albumin substances, which are split up into other substances of simpler composition—acids with which the alkalies and lime combine to form salts and organic bases.

The purifying effect of the lime on the juice is about four to six points over the purity of the pressed juice. Beets of lower purity generally have a greater tendency to eliminate impurities under the action of lime than those of high purity, and here again the purifying effect of the lime depends on the nature of the impurities, which are dependent on the season, variations in soil, etc.

The impurities of the beets are of a complicated nature. In fact we do not know a great deal about them; but we do know that the percentages of different substances, such as sulphuric acid and citric acid, which we can readily analyze and determine, vary within wide limits; and we know that certain organic substances, for instance glucose, not only vary widely in fresh beets, but increase considerably after harvesting and may reach alarming amounts by fermentation. Glucose contents as high as 1 to 2 per cent on 100 sugar are of not infrequent occurrence and, if anything acts adversely on the lime purification, it is glucose. Sugar solutions containing glucose, if treated with lime at high temperatures, do not increase in purity. Glucose is decomposed by lime and split into organic acids of high molecular weight—which combine with lime, and the amount of lime salts in solution after lime treatment can be roughly estimated. A juice with 1.5 per cent glucose on 100 sugar has after the hot lime treatment about .5 per cent CaO in solution on 100 sugar.

As the consequence of combinations of lime with organic acids resulting from glucose, such sugar solutions do not boil, offer the greatest difficulties in the vacuum pan, hinder the cystallization, and give low yields and high purity molasses. If other beet impurities acted like glucose, there would be no lime purification in the beet-sugar industry. Luckily they do not act in that way; but the conclusion is justified that with such wide variations in the constituents of the impurities a uniform percentage of elimination of the latter cannot be expected. In fact practical figures show that from 25 to 40 per cent of the impurities of beet juices have been eliminated by battery work and lime purification together.

The lime not only eliminates some substances from the juice, but ordinarily changes the remaining non-sugars so that they do not present such an obstacle to the boiling and crystallizing of the sugar (glucose being a notable exception).

In factories where milk of lime is added to the carbonation tanks, measuring tanks are generally placed on top of the carbonation tanks, one measuring tank being used for two carbonators. The milk of lime has to be kept as near 20° Bé. as possible to insure an even lime addition. The lime is usually slacked in revolving cylinders in the limekiln house with the sweet water of the filter presses and with hot water. It is pumped to the carbonators from a little lime reservoir which is provided with sieves and stirrers.

The pipe line of this pump should be perfectly free, without valves which can shut off the line, and should have a gooseneck return to the tank from which the milk of lime is pumped, so that the latter is in continuous motion and does not settle down and stop the pipe line.

The measuring tanks empty into the carbonation tanks, and a good mixture of lime and juice is effected by the carbonic acid gas which is generally pumped by means of a gas pump into the limed juice. The chemical process taking place in the carbonation is not yet fully understood. The carbonation does not simply precipitate $CaCO_3$, carbonate of lime, but there is formed a complicated double compound of carbonate of lime and saccharate and perhaps hydrate of lime. This composition is formed to a greater extent in cold than in warm juices, which may be the reason why colder juices foam more than warmer juices. As soon as the carbonic acid gas enters the limed juice the latter begins to grow thick and gelatinous, as a consequence of the formation of this double compound. It is entirely impossible to filter the juice in this condition, and if by mistake, by leaky outlet valves or the foaming over of juice from one tank to another, juice in this condition goes to the presses along with other carbonated juice, the filter cloth immediately becomes dirty and sloppy cakes with high sugar content are the result. Such gelatinous juice does not settle, but remains muddy. The gas bubbles are large and the juices foam. By and by, as the carbonation progresses toward the end, this double compound is broken, or split up, the juice becomes thinner and more liquid, the foam disappears and the gas bubbles are smaller. In factories where open carbonators are used in places which are not too noisy, the sound of the gas passing through the liquor gives a good reliable warning that the carbonation is nearly finished. Then the mud settles quickly in a sample, and, from its appearance and the rapidity with which the clear juice separates from it, the operator of the carbonation station can judge whether the carbonation is finished.

Nevertheless, he should not be allowed to depend on this test alone, but should titrate each tank. The alkalinity before carbonating at a temperature near 80° C. is around .25 to .35. During carbonating the alkalinity sinks rapidly to around .20, but stays at this point during the process, dissolving nearly as much lime as is carbonated till there is no soluble lime left in suspension; then the alkalinity decreases rapidly again.

If the carbonation is carried too far, some of the substances precipitated by the lime go into solution again, especially the coloring matter, and when this occurs the juice looks cloudy and discolored. The only remedy in such cases is to add more lime. The point at which the mud separates readily from the juice varies with different beets. Some juices separate at an alkalinity of 0.14, while others require a carbonation as low as .08 alkalinity—0.10 may be regarded as a good average. The carbonation should not be stopped too soon. Small amounts of hot trisaccharate may be suspended in the juice. These will be given a chance to dilute and to undergo carbonation when the alkalinity is kept a little lower, 0.08 to 0.12, phenolphthalein being used as indicator.

The above description applies to intermittent work, that is, work in which each tank is carbonated separately. These tanks are generally square or rectangular, and the height to which they are filled with liquor varies in different factories, as special care has to be taken that they are all filled to the same height, cocks are arranged at the surface line of the liquor and are left open during the filling, the inlet valve being shut as soon as the juice appears at these cocks. If the tanks are filled to different heights, and several tanks are carbonated at the same time, the gas will pass through the tank with the smallest counterpressure, and this tank will be carbonated before the others, even if the gas valve is partly cracked. The higher the level of the liquor, the better the gas will be utilized, for the gas bubbles will have to take a longer path through the liquor. A height of 5 to 6 feet is generally considered sufficient.

The gas distributors at the bottom of the tanks are variously constructed. They are sometimes arranged in a cross of perforated pipes, when if the perforations are on one side of the pipes and turned in the same direction, the contents of the tank acquires a circular motion which helps to mix the liquor thoroughly with the gas. Another arrangement consists of perforated gas pipes—two, three or four in each tank, set in from the outside by means of an arrangement similar to a stuffing-box. Such pipes are exchangeable, and if an extra set is kept on hand, can be cleaned without interrupting the course of the work. The smaller the holes in the pipes are the more effective is the carbonation. Small holes effect a greater utilization of the gas, but, on the other hand, they become stopped up more easily. In a factory which burns all the lime used in the carbonation, there is always an abundance of carbonic acid resulting from the burned coke, so that there is no real need of utilizing the gas to the possible limit. On the contrary, some gas has to be wasted to keep the lime kiln in proper shape.

Other designs of gas distributors have been successfully employed which are not so economical of the gas in carbonating, but which have the advantage that they cannot become stopped up and will insure a continuous run all through the campaign. Such an arrangement is a cross of inverted troughs, having serrated sidewalls through which the gas escapes in fine enough bubbles to insure a quick and efficient carbonation. A cross of this kind, of course, has to be perfectly horizontal to allow the gas to escape evenly.

The space above the liquor should be made very high. Each juice foams more or less in the carbonation and sometimes so much so that the capacity of the plant is reduced, especially with frozen and fermented beets. Plenty of room over the liquor is the best remedy—10 to 12 feet of space above the liquor is a sufficient protection against foaming over. Usually each tank has a separate stack to the roof to let out the gases which have passed the liquor. A common manifold on the roof into which these stacks lead is a good safeguard against sugar losses. These stacks enter the manifold at the bottom and are extended about 1 foot inside of the manifold, with the exception of one of them, which provides for the return of the juice to one tank. Each time this tank has to be emptied its contents should be titrated, care being taken that no juice has been thrown over into the tank; if the alkalinity is abnormal the gas has to be applied again for a short while to reduce it to normal.

Other devices to prevent foaming of the juice are perforated steam pipes 2 or 3 feet above the surface of the liquor; but those consume much live steam and dilute the juices.

Usually oil or tallow is used to keep the foam under control. For this reason oil cocks or pumps of various construction are used at the carbonation tanks. The best insurance against foaming over from one tank to another is the use of wide stacks, about 3 feet in diameter.

All carbonation tanks are provided with heating coils or direct live-steam injectors to heat up the juice. The closed steam coils are not very effective, as they become coated with a hard, thick scale and the live steam injection thins the juice. These auxiliary heating arrangements cannot be entirely dispensed with, but in the regular work of carbonation they should be used as little as possible. The juice ought to be heated high enough in the heaters between the diffusion battery and the carbonation to have a temperature of 75 to 80° during the carbonation. The heaters are most economically heated with vapor from the evaporators. In regard to heating the juice after the carbonation is finished the opinions of the experts are divided. Some advocate heating the juices in the carbonation tanks after carbonating up to 90° C., while others are satisfied if the juice is pumped to the presses with a temperature of 80° C., that is, the temperature at which the carbonating has been done. In the latter case the heating will be done after the juice leaves the presses before going to the second carbonation. This method of heating has the advantage of cheapness, because the heat can be supplied from the evaporators. Even the carbonated, unfiltered juice can be heated in fast-circulating heaters without incrusting the tubes.

The above description applies to intermittent carbonation only. Continuous carbonation involves very different features. Continuous carbonation requires a separate arrangement for the addition of lime. In continuous carbonation, where the bulk of the carbonating is done in one tank, the juice is always in a state approaching carbonation. The limed juice enters the tank and is rapidly mixed with the nearly carbonated juice, so that there is very little or nothing present of the gelatinous double compound of carbonate of lime and saccharate of lime. On the other hand, continuous carbonation requires still more careful watching on the part of the operator. Over-carbonated juice cannot be regulated as easily as in intermittent carbonation. However, as continuous carbonation is not very widely practiced in this country, we shall not take time to describe it. The efficiency of the carbonation gas is lower in continuous carbonation than in the intermittent process, on account of the almost saturated condition of the liquor. Irregularities in the carbonation sometimes occur owing to irregularities of the gas pumps or gas washers and to stopping of the gas lines with ashes from the kiln. It is advisable to have in the suction line of the gas pumps at different places, before and after the gas washers, little U-pipe water vacuum meters; these promptly show where there is clogging and whether the valves of the gas pumps are working as they should.

Another irregularity is very apt to occur, especially after the campaign is a little advanced, and this is caused by hard scale falling off from the walls and pipes of the carbonators and getting under the seats of the inlet and outlet valves. Thus non-carbonated or partly carbonated juice might be pumped to the presses, dirtying up the filter cloth, a happening easily detected by titrating the juice at the presses and at the carbonation tanks, when there will be a complete disagreement of the different titrations.

CHAPTER VIII

FILTER PRESSES

FROM the carbonation tanks the carbonated juice either goes to a carbonation receiving tank or is pumped directly to the filter presses. The pumps used for this purpose have been mostly steam pumps or belt-driven plunger pumps, though in recent years, two-stage centrifugal pumps have been used and have given very satisfactory results. In the suction line of these pumps two stone-catchers are generally interposed, which can be alternately cleaned. The stone-catchers are necessary to catch the deposits or scales from the carbonation tanks and keep them out of the pump and valves, thus preventing the small channels in the filter presses from clogging.

The pressure used for filtering varies in different factories, but it is advisable not to use too high a pressure. A pressure of around 3 atmospheres is usually adopted. At this pressure it seems possible to obtain cakes which are good and hard, but not too hard to insure a thorough and easy washing of the presses. For that reason the filter press pumps should be provided with pressure gauges at the pump itself and in the line near the filter presses. The pressure should be regulated at the end of this line by a pressure-regulating valve with a return line to the suction line of the pump. There ought to be a valve in the discharge line of the pump to be closed when there is any repairing or cleaning to be done at the pump. This latter remark applies to all pumps in the house which have a long discharge line, otherwise the whole discharge line has to be emptied before the pumps can be opened.

Most of the filter presses used in modern houses are now constructed with side-inlets for the material to be filtered, with alternate frames and plates, either filling from the bottom or from the top of the press. The use of old-style presses with central filling channels is so nearly abandoned that they will not be discussed in this treatise. The plates of the modern presses are either provided with perforated sheet-iron screens or have deep vertical grooves, as well as some horizontal ones, at the top and bottom of the plate. The former plan permits the center of the plate to be independent of the frame and attached to it by means of the screens. This arrangement protects the plates from breaking, if one of these channels becomes stopped up through negligence, or on account of the presence of a piece of scale in the filling channels. In such a case, if there is a hollow frame between two full ones, these flexible central pieces will curve in and the damage will only extend to the screens, which can easily be repaired or replaced. On the other hand, the presses with screens are not so easily cleaned as the grooved plates; but since this final cleaning, is not usually necessary during the work, but only after the campaign, this objection is less serious.

These filter presses generally have one wash-water channel, and wash through the cake and out through cocks at the bottom of the neighboring plates. Therefore in a filter press of this sort there are two different kinds of plates, generally called water plates and juice plates. The cocks used for the filter presses are either stop cocks or pistol cocks shut by a lever, and they are made of cast iron or bronze, the latter being more resistant. Opinion is divided as to which kind of cock is preferable. It is desirable to have a straight outlet channel, and for that reason some designers put these cocks at an angle of 45° and use a straight cock, such an arrangement enabling the operator to clean the channels and cocks with a piece of wire, without detaching the cock from the plate.

By plugging up the outlets of the water frames and conducting the juice through the water channel and a special pipe connection with valve to the juice trough, it is possible to do away with the cocks altogether.

The juice and water channels are tightened either by rubber rings or by sewed sleeves of the same material as the filter cloth. Which is the better way of the two seems to be undecided, some preferring the rings, some the jute sleeves. The filter cloth used in the first filter presses is usually a coarse jute which is laid double, a lower and an upper cloth being used. Some factories use a jute undercloth and a cotton upper cloth to insure a better filtration though the use of two jute cloths is more common. There is also much variation in the quality of the jute, some factories using a heavy, closely meshed cloth, others a considerably looser and cheaper material. The latter naturally does not last as long as heavier cloth of better quality, and may not stand any washing at all. In this case the filter cloth will be left on the presses till it has to be renewed and the old cloth thrown away. Better and heavier cloth is generally washed repeatedly, but as this causes considerable shrinkage, the filter cloth has to be ordered wide enough to allow for this. An overlapping of an inch on each side of the plates for plates of 30 to 40 inches width and, in the other direction, an overlapping of 4 inches on both ends of the cloth for plates of the above mentioned size may meet the shrinkage. Different materials will show a different shrinkage and the best way to find out how long the cloth has to be cut will be to make a shrinkage test. In later years duck cloth has widely replaced the jute.

The washing of the filter cloth is usually done in cylindrical washing machines with several chambers made of slats, which revolve in hot water, reversing their direction at intervals. The cloth is thrown heavily by this reversing motion and these washing machines are quite satisfactory.

Clean work at the filter presses is indispensable. The channels of the juice inlets to the frames have to be watched carefully, the filter cloth must not fold or double, the faced joints of the frames must be kept clean, and so on. The more care taken in emptying, cleaning, and shutting the presses, the less often will the presses leak and have to be reopened. The size and capacity of the first filter-press station varies in different factories according to the lime addition and the filtering capacity of the juice; but to give an approximate idea of the dimensions used in this country it may be said that for 1000 tons of beets with 3 per cent lime addition on beets a filtering surface of 550 square meters is considered sufficient. The thickness of the cake in the first filter presses has been standardized, from experience, at about 25 mm. With healthy juices correctly treated in the diffusion and the first carbonation and with 2.5 per cent of lime addition, it might be possible to produce thicker cakes; but the condition of the beets varies with the stage of the campaign (first green beets, later frozen or fermented beets, all affecting the filtering ability of the juice), so that it is advisable to adopt a thickness which has been shown to meet most, or almost all, of these conditions. It would not be advisable to have presses producing cakes of different thickness in the same first filter-press station, because the different presses would not work together as well as those of the same construction. The size of the presses ought to be adapted, furthermore, to the size of the house in so far as there are enough presses going all the time to keep up the work, when the full presses are cleaned. There is, however, an advantage in having large presses, because they require fewer men to operate them than smaller ones. In enlarging a house the same type of presses should be added, so as to have as uniform a press station as possible.

There are two methods of filling the presses. Some operators work their presses in sets. When there are nine presses, for instance, three presses are filled at the same time, three are sweetened off, and three are emptied. In this way the pressure in the filling line disappears entirely when three fresh presses are opened. The juice enters the empty presses freely, the presses gradually fill up with mud, and the pressure rises just as gradually. When the presses are filled the pressure in the main line is up to the desirable height. The emptying of the full presses will have been completed in the time it takes to fill the empty presses, so that the cleaned presses are ready to take the juice when the first set is closed and sweetened off. Then the pressure in the main line disappears again. The other method of working is continuous. A certain number of presses are filled, the valve of the last press being only cracked at the beginning, so as to maintain the same pressure in the main line; and accordingly as the first presses fill up, the valve of the last one is gradually opened till at the last it is wide open. Then another press is started; but the same pressure is always maintained in the main line. When a fresh press is started at the head of the circle a full press is switched over to be sweetened off and the first one in the cycle is cleaned. The choice between these two methods is a matter of individual preference and does not seem to have any influence on the quality of the work. Inside of the newly opened press the same conditions exist in both cases. Behind the partly cracked valve of a fresh press there is just as little pressure as when three presses are started at once.

The presses fill up from the blankets toward the center of the cake, not from the bottom to the top. In the beginning, when the cake is soft, the heavier particles of sand and grit may be more inclined to sink down to the bottom; but the layers of mud are almost uniform at the top and at the bottom of a press. These layers can be seen when a cake is broken and they result from differently colored mud. The mud of each carbonation tank in the intermittent carbonation has a slightly different color, and these differently colored layers are of the same thickness at the top of the press as at the bottom. The cake resulting from the continuous carbonation does not show these layers.

If a press has to be opened for any reason before it is properly filled, the mud cake hangs in two halves from the two filter cloths between which it has been formed, showing the soft central sheet which divides the two halves. This shows the possibility of sweetening off through the juice channel. If the sweet water is forced through the juice channel, the water penetrates the softer central layer and goes out between the two halves, just as the juice did. This way of sweetening off the presses is, however, far inferior to the regular way of sweetening off from one side of the cake through the whole cake. If, in the case of sweetening through the juice channel, the press is filled for too long a time, the central soft layer fills up and finally gets too hard to admit the water, and in that case the cake will sweeten off only in the vicinity of the inlet channel of the water. It takes much more care on the part of the operator to sweeten off the press in that way than through special sweet-water channels.

The pressure used in the sweet-water pump depends largely on that used in filling the presses. The pressure of the sweet-water pump ought to be determined by experiment, and the conditions which regulate this pressure are that the press is to be sweetened off to about 1 per cent of sugar in twenty to thirty minutes with as little water as possible.

The cake before it is sweetened off at all has about 6 to 7 per cent of sugar. For sweet-water the hot condensed water of the evaporators and heaters is generally used, and there is usually an abundance of it. The first part of the sweet-water from the presses generally goes to the juice; the thinner part is used for slacking the lime and returns in the milk of lime to the presses. In factories using Steffen's separation the sweet-water is used to mix up and thin down the saccharate.

Irregularities in the filter presses are often caused by leaky outlet valves at the carbonation. In this way non-carbonated juice may be mixed with the carbonated juice and will immediately dirty the filter cloth; or juice which is not fully carbonated may be thrown over from one tank, through the common manifold above the carbonation tanks, into another tank which is pumped to the presses, an event most likely to occur where the common manifold is directly above the carbonation tanks. It is, therefore, better to have this manifold at the end of the stacks on the roof. When a mixture of uncarbonated and carbonated juice occurs a titration at the presses will reveal the fact, and it will be easy to find the cause; but there are cases where the first filter presses do not run normally and no such reason can be assigned. The condition of the beets has much to do with the filtering capacity of the juice. The green beets which are received in the beginning of the campaign often give juices which are difficult to filter; and the inexperience of the workmen during this part of the campaign naturally increases the difficulty. Juice of fermented beets also causes trouble in the presses. In this case a reduction of the temperature in the battery will be of some assistance, and will also be advisable for the battery work itself.

In some cases repeated cleaning and changing of the filter cloth is the only remedy. With such a high lime addition as 2.5 to 3 per cent on beets, however, the difficulties at the first filter presses will seldom be so severe as to reduce the capacity of the house.

The main objection to the plate and frame presses is that they require quite a large amount of hand labor and, since the labor question is becoming more and more serious, other presses have been designed which require less hand labor. These presses are constructed more or less after the principle of the old danek bag filters, the most widely used type of this kind being the Kelly press, which consists of an iron cylinder with a movable head to which bag filters are attached. When closed, the whole press is tightened by one gasket; and this must be considered an advantage. The press is filled with carbonation juice and run till the cake formed on the outside of the bags has a certain thickness. If run too long, the whole press fills up with mud and such a press cannot be washed.

Indicating devices have been designed to show when the press is filled to the right thickness of cake on the bags but they are more or less unsatisfactory.

After the press is filled a slight air pressure drives out the excess juice into the cabonation receiving tank or into a separate tank, such pressure holding the cake in its position and preventing it from falling off. Then the washing is started with the last sweet-water and excess water from the previous operation, followed by clean water; and the washing is finished when the sweetwater has a certain density. Then the excess wash water is emptied into the excess wash-water tank under a slight air pressure, which is increased after the excess water is expelled and the cake is blown out with air. Finally the press is opened and the front head, together with the bag filters and mud, is pulled out of the cylinder by a mechanical device, the mud being washed off from the bags with water under pressure from an operating bridge into the hopper underneath.

The hand labor is undoubtedly reduced, and that is the greatest advantage of this press; but it requires far more wash water than an ordinary plate and frame press. The cake is seldom uniformly thick and parts of the mud often fall off from the filters between filling and washing, so that no washing can be done. Furthermore the excess wash water has to be taken care of. These points make the Kelly press worthless for saccharate cake. For the hot carbonation presses these conditions are not so detrimental, resulting simply in an additional tax on the evaporator station and the boiler house. The main objections to the Kelly press in this station are the unevenness of the cake, the resulting irregularity of the washing and higher sugar losses, and it is an open question whether these disadvantages are offset by the saving of labor.

A house of 1000 tons capacity which uses 2.5 per cent CaO for defecation will have about 10 per cent of lime mud; if this is sweetened off to 1 per cent of sugar, the actual sugar loss is .10 per cent on beets. However, the washing of the presses is such an important factor in reducing the sugar losses and a rushing of this process is sometimes so tempting to the men that a double laboratory control of this washing is most desirable. Such a double control is made possible by analyzing the contents of the mud flume, especially in factories where the mud has passed an efficient mixer before being flumed out to the mud settling pond. An analysis of the lime mud from the presses and from the flume for sugar and CaO shows the proportion of sugar to CaO in both samples and indicates whether more sugar is lost on this press station than would be indicated by the mud from the presses alone.

The lime mud may fall through spouts into wagons and be carried on rails to dumping places, or the press may be emptied into a closed hopper mixed with water and flumed out to lime mud settling ponds. This lime mud contains all the substances precipitated in the first carbonation, and among these there are some fertilizing substances such as phosphoric acid and nitrogen. The percentage of these fertilizers is very variable and depends largely on the amount of lime used in the carbonation. When the lime addition is 2.5 to 3 per cent on beets, as in most of the white sugar factories, the amount of phosphoric acid is hardly over 0.2 per cent and of nitrogen 0.3 per cent so that the fertilizing value of the mud is small and the cost of hauling a load of the lime mud is greater than the value of the fertilizers it contains. But the lime itself is beneficial to heavy clay soils and it certainly pays to treat such soil with a large quantity of lime mud, which improves the physical condition of the clay and at the same time adds the above mentioned fertilizers. If it is possible to flume the lime mud out with pulp water, more organic matter will settle out with the lime mud, and this, in rotting, will help to improve heavy clay soil. Sandy soil may also be improved by the addition of lime mud.

CHAPTER IX

AFTER-PURIFICATION—SECOND CARBONATION—SULPHUR STATION FILTRATION

The juice coming from the first filter presses with an alkalinity of about 0.10 goes to the second carbonation, at least in most of the American beet-sugar factories, which are equipped with a first carbonation, second carbonation, and sulphur station. On the way to the second carbonation some of the factories have additional reheaters, which bring the juice almost to the boiling-point. The heat should be supplied by vapor from the evaporators. If there are no heaters here, the heating must be done in the second carbonation with live-steam coils. It is of fundamental importance in the whole after-purification to keep the juice as hot as possible. At a high temperature the lime acts more energetically on the non-sugars of the juice, and lime salts of the higher organic acids like citric acid are precipitated more fully at a high temperature than at a lower one. The precipitate itself is more crystalline and filters better at a high temperature, and the formation of lime bicarbonate is prevented. For all these reasons a hot treatment of the juice in the after-purification is absolutely necessary.

Some factories add about a quarter of a per cent of lime, in the second carbonation; some do not. The influence of this second addition of lime is slight; but it may be of value in case of irregularities in the first carbonation or if the first filter presses did not run clear, in which case the precipitate in the second carbonation may become slimy, and on addition of lime will facilitate the filtration in the second presses or daneks, whichever may be used, after the second carbonation.

Various factors determine the point to which the alkalinity should be reduced. Some factories have no sulphur station for thin juice, but finish the saturation with carbonic acid, when, of course, the carbonation has to be carried farther than if a third saturation were to follow. If there is a sulphur station, enough alkalinity should be left in the second carbonation to get a good precipitate in the sulphur station. An alkalinity of .015–.025 may be considered best in factories with a third saturation.

Some factories run the second carbonation continuously and for that purpose have three tanks. The receiving tank, into which the juice runs from the heaters or first filter presses, has to be provided with large heating coils. Through an overflow the juice enters the second tank, where it is carbonated; and from there another overflow takes it to a third tank whence it is pumped to the second filter presses, or flows by gravity to daneks. A similar arrangement will serve for the sulphur station.

The filter presses for the second carbonation are generally similar to the first presses provided with sweet-water channels. Some factories, however, do not sweeten off the mud in the second filter presses but stir it up with a little juice and add the mixture to the carbonated juice of the first carbonation to be filtered in the first filter presses. The object of this proceeding is to have very simple second filter presses and to save a little sweet-water.

From the second filter presses the juice generally goes to the sulphur station and is saturated with sulphurous acid to the final alkalinity, concerning which latter there is a diversity of opinion among the sugar experts, some preferring a high alkalinity, some saturating almost to neutrality. Although the bleaching effect of the sulphurous acid is stronger in almost neutral or slightly acid juices, and such juices have a brighter color, the influence on their purity is so slight that the writer was not able to discover any increase in purity after sulphuring. The bleaching effect of the sulphurous acid is often overestimated.

Juices which are almost neutral easily turn acid, and since they are exposed for some time to temperatures of over or near 100° C., there is great danger of inverting some sugar. It is far safer to keep a little higher alkalinity in the thin juice and to regulate the final alkalinity by the alkalinity of the thick juice. The alkalinity of the thin juice is not always caused by lime or alkalies, but often by ammonia. This alkalinity readily disappears in the evaporators and is replaced by neutrality or even acidity. This is especially true at those parts of the campaign when green, frozen, or fermented beets are worked.

The lime present in such juices is not hydrate of lime or lime saccharate. On the contrary, juices from fermented beets usually contain much lime in form of organic lime salts, so much so that they have a detrimental influence on the formation of sugar crystals in the pans, and such juices turn acid more easily than normal juices. It is, therefore, advisable to regulate the final alkalinity of the thin juice by the alkalinity of the unsaturated thick juice. That is, if an alkalinity of about 0.05 to 0.07 in the unsaturated thick juice is wanted, the alkalinity of the thin juice must be kept high enough to obtain that desired in the thick juice after concentration. With normal thin juices an alkalinity of 0.005 to 0.015 is high enough to insure against inversion, and to obtain the above mentioned alkalinity in the thick juice.

The sulphurous acid installations used in the various sugar factories are diverse. Some factories use compressed liquid sulphurous acid, which they store in large wrought-iron tanks. Since this liquid sulphurous acid evaporates at common temperature under three atmospheres of pressure such installation is a very simple and convenient one, requiring only some pipe connections to the sulphur tanks. Other factories burn sulphur in open furnaces, sucking the necessary air through the kiln by means of a steam injector. With this arrangement the live steam heats the juice, but it thins it down at the same time. The steam injectors are very delicate, as only a few materials will stand the action of the sulphurous acid combined with steam. A certain hard lead composition or porcelain is used for this purpose. Some factories pump the juice through injectors and suck the sulphurous gas into the juice by this means.

To avoid the difficulties mentioned, most factories use closed sulphur stoves, an air compressor pumping the air to the sulphur and the sulphurous gas to the sulphur tanks.

In handling such a sulphur stove great care must be taken that the stove and the discharge pipe line are properly cooled, otherwise the heat produced in the sulphur stove may rise to such a degree as to sublime some of the sulphur. Sublimed sulphur is likely to get into the pipes and clog them. In addition to the common water jackets around the kiln and cooling tower it will be of advantage to have a large cast-iron receptacle placed on top of the cooling tower and cooled with water dropping from the outside.

The discharge line of the sulphur stove must have a small outlet to the air to permit a small circulation of air and a reduced burning of sulphur in case there is no sulphurous gas used in the sulphur tanks, otherwise the fire in the stove will be smothered and the disagreeable work of lighting it will have to be repeated after each stop of any length of time.

The sulphur stove should be lighted by means of a small manhole on the top, through which a piece of red-hot iron can be thrown in.

The sulphur pipe lines at the sulphur tanks and the steam lines should be separated. It is a mistake to have steam connections to the sulphur pipes, because any material will be more or less corroded after a while by the sulphurous gas, the valves in the steam line will begin to leak, and sulphurous gas and steam together eat the material more rapidly than dry sulphurous acid alone.

The sulphur valves are, as a rule, a weak spot in the factory. All kinds of materials have been proposed for them, such as cast iron, hard rubber, soft rubber, pottery, hard lead, etc., but experiment has not yet revealed a thoroughly satisfactory material for this purpose.

Some factories add soda ash to the thin juice. The most convenient place to add such chemicals is in the troughs of the second filter presses or in the daneks, before the juice enters the sulphur station. Normal juices do not need any addition of soda ash, and whether it has a good influence on juices with a large amount of organic lime salts is open to question. The only possible reaction of soda ash on such salts would be to precipitate calcium carbonate. The sodium would replace the lime, and it is very doubtful whether the soda salts of those organic acids influence the crystallization of the sugar less than the lime salts. We know that a rather high percentage of certain lime salts in otherwise normal juices does not hinder the crystallization of the sugar to any great extent; and it is more than probable that it is the specific organic material combined with the lime in such juices which causes the difficulties in the pan. It is more advisable, in the case of frozen or fermented beets, to fight the difficulties in the diffusion battery by reducing the temperature to the lowest possible degree, to observe the right temperatures in the purification, and to mix the fermented beets with healthy ones, if there are any, rather than to improve the juices by the addition of chemicals.

In the cases of a high ammonia alkalinity an addition of sodium hydrate is sometimes made to insure a slight alkalinity after the ammonia has evaporated. Other chemicals which are used in the thin juices are phosphoric acid in various forms to precipitate lime as lime phosphate, barium hydrate, magnesium hydrate, alkali salts of hydrosulphurous acid, lead, metallic powdered zinc and tin, etc. Some of them have a bleaching effect, especially in combination with sulphurous acid, but they are expensive. Some powdered metals with sulphurous acid cause inversion; some are poisonous or hard to eliminate from the juices after they have once been added. They are not generally used in the sugar industry. Electrical treatment of the juices has been tried with good bleaching effect, but is as yet too expensive.

One of the most important points to be considered in superintending a beet-sugar factory is the filtration of the juices. The more care is taken to conduct every filtration properly the better the juices will be and the cleaner the evaporators will remain. It is a mistake to think that a leak does not amount to much as long as there is another filter station to follow the filter which runs badly. If the first filter presses run cloudy, part of the precipitate of the first carbonation enters the second carbonation and, the juice being carbonated down to a low alkalinity in presence of first carbonation lime mud, the same bad effect is produced which we found to be the result of over carbonation, at the time of the first carbonation, only, of course, to a much slighter degree, because the bulk of the mud has been taken out.

Leaky blankets in filter presses with wash-water channels cannot very well be cut out by closing the respective cocks, because the liquor goes through the wash-water channel out to the next frames; they must be replaced when the filter press is emptied.

In daneks, a leaky bag should be shut off by means of wooden plugs, which should be kept in a convenient place near the daneks, because the more trouble it is to shut a leaky bag, the more likelihood there is that a little cloudiness will be neglected by the operator. A description of the filter presses is given in the chapter on "Filter Presses."

The daneks are bag filters in which the juice is filtered from the outside of the bags to the inside. There it enters a split pipe through which it flows out to the troughs. The joint of each bag filter to the outlet nozzles is usually tightened with rubber rings, and these rings have to be watched to insure a tight closing. There ought to be enough rings in reserve to replace the old ones whenever they give out.

As a rule, the filtering material is cotton bags of good quality, which are washed when dirty and have to be looked over carefully for holes before being put back into use. If necessary, they must be repaired. The daneks are either open or closed. The open daneks, which are generally used for thin juices, are under a very small pressure, viz., that of the juice which is filtered. The highest pressure exists only when the whole danek filter is full. The outlets are only 1 foot to 1½ feet below the top of the danek. This low pressure is a great advantage, as the juice can never be forced through a danek filter, and the filtered juice is generally bright and clear, unless there are holes in the bags or leaks at the joints. In this respect the open daneks are ideal filters for an after-filtration. Juices containing large amounts of lime mud are filtered better through filter presses, hence the latter are generally used for the first carbonation juice and also for the second, especially when there has been a second addition of lime. Daneks are usually employed at the sulphur station. If there is much lime mud to be filtered, daneks fill up too quickly. They cannot be sweetened off without using an enormous amount of water and they have to be cleaned too often. A danek filter generally holds a large amount of juice, and all this juice has to be cleaned out into a tank whence it is pumped for the second time through the same filter station (second presses). Closed daneks allow a pressure of 3 to 4 m., but are generally used for thick juices. They will be discussed later.

The importance of having a thorough filtration for the evaporators is so great that many operators are not content with having only one filtration after the last saturation, but filter the thin juice twice before it goes to the evaporators. Here different kinds of filters are used, such as filter presses, followed by daneks or excelsior filters, or sand filters of different construction. Of these after-filters the sand filters are the most important and the most commonly used, and are indeed unsurpassed by any other device for after-filtration. They are used for thin or thick juices.

In closing this chapter we repeat what was said in the beginning, that the strict observance of as high a temperature as possible throughout the whole after-purification is one of the most important points in obtaining the purest juices with the easiest filtration.

CHAPTER X

EVAPORATION

From 1000 kg. of beets of 16.5 per cent sugar, an average of 125 per cent of juice may be drawn off in the diffusion battery. With the wash water of the presses there may result a thin juice of 11.5 polarization, which would mean, in rough figures, 140 per cent of juice.

1400 kg. of thin juice with 160 kg. of sugar give about 280 kg. of thick juice of about 60 Brix, therefore there is to be evaporated from 1000 kg. of beets $1400-280=1120$ kg. of water. These figures are for beets high in sugar; for beets lower in sugar the amount of water to be evaporated is smaller, but since California, Utah, and Colorado may figure on beets of a high sugar content the figures given above will be employed.

A factory which undertook to evaporate such an amount of water directly, or in a single operation, could not exist, as the coal consumption would be over 30 per cent on beets for the evaporation of the thin juice alone. This evaporation is effected in evaporator stations of various types. The common feature of the different types of construction is that several evaporator bodies, from three to five, are combined and the first body is heated by the exhaust steam of the factory. If this is not sufficient, live steam must be added. The steam enters the heating chambers of this first body and is condensed to water, giving up its apparent heat (the difference of temperature in and outside of the heating chamber) and its latent heat, through the metal of the heating chamber, to the juice in the juice chamber, which absorbs this heat and evaporates a corresponding amount of water. The steam produced from the juice, generally called vapor, enters the heating chamber of the next body and here the same process is repeated; the second body heats the third body, the third heats the fourth, and so on, the vapor of the last body going to a condenser, where it is condensed into water by the injection of cold water.

The condensation of the water creates a vacuum which reduces the boiling temperature of the last body; thereupon the condensation of the vapor in the steam chambers of the last body creates a vacuum in the one next to the last, a process which is repeated in each body. So we find a gradual fall in the temperature and in the pressure, from body to body. The condenser is connected with a vacuum pump, the object of which is to take away the uncondensable gases, viz., ammonia, carbon dioxide, and the air coming from the juice and from leakages of the system. The gases named are produced in all bodies of the evaporators and if they were not constantly being conducted by small pipes either directly to the condenser or to places of a higher vacuum they would gradually fill up the heating chambers of the next body, thus decreasing the space for the condensable vapor.

An installation cannot be considered good, if the ammonia pipes of each body are led into a common manifold, unless this manifold is of a large size, because a small opening of the ammonia valves of the first bodies, due to the higher pressure, will release a comparatively large amount of gases and steam which may check the wholly opened ammonia cocks of the last body and partly or entirely prevent the ammonia from leaving the heating chamber of this body. It is safer to lead the ammonia pipes from the heating chamber to the juice chamber of each body.

It is easy to see that the last body represents the condenser for the one next to the last, while this one in turn is the condenser for the body ahead of it, and so on throughout the installation. The last body can evaporate only as much water as corresponds to the water condensed in its heating chamber from the body next to it, disregarding the losses of heat and the difference in temperature of the condensed water and the boiling juice at the other side of the tubes, and assuming that each body heats only the next one, and no vapor is taken away for heating purposes, the amount of water condensed in each body is approximately the same. This is only approximate; a quadruple effect will not evaporate four times the weight of the heating steam, but about 3.8 times this weight. So it appears that, in estimating the heating surface of an evaporator station, the calculation should start with the heating surface of the last body.

The evaporating process, or the transmission of heat from the heating chamber to the juice chamber, depends largely on the circulation of the juice along the heating surface. With a low juice level in the evaporators the circulation is more rapid and at the same time the counter-pressure on the steam bubbles in the lower part of the evaporator is diminished—factors favoring the heat transmission.

For a good heat transmission the drainage of the condensed water from the heating surface and out of the steam chamber must be as perfect as possible. Perfect action on the part of the ammonia valves materially influences the capacity of the evaporators. These valves must lead off the uncondensable gases to make room for steam which can condense and give up its high latent heat to the juice. The evaporation is further influenced by the viscosity of the juice and naturally, in this connection, by the temperature of the juice.

The heat transmission is proportional to the difference of temperature between the different bodies, and this difference is much greater in a triple than in a quadruple effect; so that, with the same heating surface per body, and with the same temperatures in the first and last bodies, the triple and the quadruple effects show approximately the same efficiency of the heating surface, though not the same economy of coal.

The evaporation is further influenced by the condition of the heating pipes. The nature of the metal has an influence on the evaporation, brass tubes being generally used. The thickness of the tubes has only a slight influence on the transmission of heat; more important than this is the condition of the surfaces of both sides of the heating tubes. In iron tubes, on the steam side, oxidation of the metal may cover the surface with oxide, which is a bad conductor of heat, and oil from the exhaust steam of the engines often settles on the heating surface, materially reducing its efficiency. For this reason oil catchers are often installed in the exhaust steam line going to the evaporators. On the juice side, the heating pipes may become incrusted with a deposit from the juice, organic lime salts, silicates, sulphates of lime, and carbonate of lime being the principal components of this incrustation. With normal juices which are kept near the boiling-point throughout the after-purification, the incrustation is generally the heaviest in the last bodies, and it increases until after a while (two weeks) it is necessary to remove it. The nature of the incrustation determines which method of cleaning has to be employed. In vertical evaporators mechanical cleaning is possible, but it involves so much hand labor and proceeds so slowly that a cleaning with chemicals is generally preferred. If it consists mainly of carbonate of lime, boiling with hydrochloric acid will dissolve the precipitate, while if the latter consists mainly of sulphate of lime, a previous boiling with sodium carbonate, or soda ash, is necessary.

The carbonate of soda converts the lime salts into carbonates of lime, and the corresponding sodium salts which stay in solution pass out to the sewer; then the evaporators are filled again and boiled with a thin acid solution. The boiling with sodium carbonate should last two to three hours, the boiling with acid one to two hours, depending on the strength of the solutions. During the boiling out of the evaporators the temperature ought to be kept as high as possible by reducing the water in the condensers. In some factories the different bodies are boiled with open manholes under atmospheric pressure. The chemical reactions take place more rapidly at higher temperature. After boiling with acid the evaporators are washed out with water before they are put in use again. By proper arrangement of a special soda tank and proper connection of the sewer lines, the boiling-out process can be conducted without interrupting the work of the rest of the evaporators, one body being cleaned at a time.

The two main types of evaporators now in use in beet-sugar factories are the vertical and the Wellner-Jelinek evaporators. The vertical ones are cylinders containing two tube sheets into which the heating tubes are fastened. There is generally a large circulating pipe in the middle of the body. The ammonia pipes in such evaporators have to be at the upper tube sheet and as far as possible from the inlet of the steam or vapor, and they must not project through the plate, because in that case there would be a space under the tube sheet where the lighter gases would accumulate and could not be drawn off. The juice in these evaporators is inside of the tubes, the heating steam and vapor outside of them. The drainage of the condensed water is at the lower tube sheet, preferably in different places to insure a rapid drainage. The space over the upper tube sheet is generally rather large, about 3 meters, to insure against juice being thrown over into the heating chamber of the next body.

Often there are juice catchers in the vapor line from the juice chamber of one body to the heating chamber of the next. They are generally cylinders in which perforated sheets are fastened; the vapor, passing by and through the many small holes, comes in contact with a large surface, allowing the juice drops to settle at the surface of the iron and drain down to the bottom of the juice catcher. Then the juice goes back through a pipe into the evaporator from which it came.

There is a series of sight glasses at the front of the body and generally one sight glass at the rear, behind which light should be placed to light up the interior of the evaporator.

Sometimes the juice foams, especially when over-carbonated. The addition of oil generally helps in such cases, and therefore oil cocks should be attached to each body of the evaporators.

As a rule, the interior of the evaporator is absolutely clear, but sometimes it looks foggy, a mist of fine juice drops making the opposite light appear to be surrounded with a blue haze. In this event it is advisable to test the evaporator, at the next clean-up day, for leaky tubes. Steam drawn through leaks into a chamber of lower pressure atomizes the juice and often causes the above mentioned fog.

For the purpose of testing, a water connection to the steam chamber should be provided. Should there be leaky tubes, plugging with wooden plugs on both ends is the quickest remedy, or the tube may be shut off by means of a long screw with iron and rubber blades on both ends of the tube.

The drainage of the condensed water from the first heating chambers does not usually offer any difficulty. In the heating chamber of the first body there is pressure, and the outlet has to have a trap; but as there is a rather high vacuum in the heating chamber of the last bodies, the evaporators are generally placed high enough to allow the water a free flow by gravity to the hot-water seal-tank. The condensed-water lines ought to have a free vertical fall from the body and may lead to the seal-tank in horizontal lines, after they have reached such a depth as to insure a water-column equal to or higher than the vacuum in the heating chamber. Elbows and long horizontal lines directly under the evaporator ought, by all means, to be avoided. If the evaporators are not placed high enough to insure a free fall, pumps must be used to pump out the condensed water.

The outlets of the condensed water from the heating chambers of the different bodies should be attached close to the body, with a $\frac{1}{2}$-inch pipe leading to the juice chamber of he same body, in order to create a suction and facilitate he outflow of the water. If the different outlets of the same body enter a common pot from which they go to the seal-tank, the pot ought to have a connection of this kind.

Sometimes the condensed water of one evaporator body is led through a U seal-pipe into the heating chamber of the next body, in order that the greater heat of this water may be utilized; but the advantage of this arrangement is counter balanced if even a small part of the next heating surface is covered with water. Another disadvantage is that U seals very seldom work as they should.

The heating chambers of all the bodies ought to be provided with water column gauges, so that any irregularity or any leakage of the pipes, which would have a tendency to retain the water in the heating chambers, can be easily detected. Water in the heating chamber of any body is indicated, furthermore, by a hammering sound in that body. To regulate the height of the juice in these evaporators there is a juice gauge connected with each body of the evaporators. The juice level should be kept at such a height that the boiling juice just circulates from the heating tubes over the tube sheet down through the circulation pipe. The vacuum and temperature in the different bodies should be provided with vacuum gauges and thermometers, in order that they may be controlled.

For cleaning purposes, each heating chamber requires a live-steam connection; and there are usually butterfly valves in the vapor lines leading from one body to the next. These valves may be shut when the body ahead is cut off and live steam is being used in the following body. The live steam connection on all the bodies except the first should have a common valve which is always kept locked with a chain, except during the cleaning period. It is surprising how often these valves are misused. Any steam entering the evaporator system at any other place than in the heating chamber of the first body keeps the bodies ahead from evaporating that much water and weakens the efficiency of the whole system.

The other type of evaporators commonly used is the Wellner Jelinek, which is a body of a trunk-like shape, the heating tubes being arranged in bundles near the bottom. Here the juice is outside of the tubes and the steam or vapor inside. The steam enters at the rear of the apparatus, goes through a set of bundles of heating pipes to the front, then returns through another set of tubes to the rear and thence to the front. These pipes are generally of a small diameter; therefore special care should be taken to see that they drain properly; otherwise the water will stay in them and cover a part of the heating surface. If the tubes have a slight inclination in the direction of the steam, good drainage is assured. The pipes are generally fastened into the tube sheets with flanges and rubber gaskets. The space between the bundles of pipes takes the place of the circulating pipes in the vertical cylinder evaporators. The ammonia pipes are at the end of the last bundle, because the lighter gases are driven by the heavier vapor to the end of the heating chamber. These evaporators, like the vertical ones above described, are provided with oil cocks, thermometers, vacuum gauges, drain pipes for the condensed water, water column gauges at the heating chamber and juice gauges at the juice chamber. What was said of the vertical type applies also to the Wellner Jelinek. Both systems are very much alike in principle. These evaporators should be filled to such a height that, during the boiling, the upper tubes are just covered with juice.

A good many other types, such as the Lillie evaporators, have been constructed and are in use in refineries and in some beet-sugar factories; but they are not yet in general use. These evaporators provide for a more rapid mechanical circulation of the juice, that is, the juice is pumped from the bottom of the apparatus to the top by means of a centrifugal pump and flows down over the heating pipes in a thin stream. They have a greater efficiency per unit of heating surface than the types above described; but are much more complicated and the economy in the use of steam is small. The main objection to them, however, up to the present time, is in the small amount of juice present in these evaporators as compared with the large amount in each body of the other types. The great volume of juice in the old type evaporators represents a reservoir of heat and, whenever vapor is used in the house for heating purposes and fluctuations occur in the use of steam, the large amount of juice and heat present in the bodies of the old type equalizes these fluctuations by faster or slower evaporation. Provisions have been suggested, however, which may perhaps overcome this objection in the future.

For the following calculations we shall consider only the old types of evaporators, for which the heat transmission coefficients are approximately the same and are commonly accepted.

The coefficient of heat transmission is the amount of heat transmitted per 1 square meter in one minute per 1° C. difference of temperature.

The amount of heat transmitted through a square meter of heating surface differs considerably in the various bodies, as stated above. The thick juice body has comparatively cold juice of higher viscosity than the thin juice bodies, and therefore a lower heat coefficient. To counteract this, it is desirable to have a greater drop in temperature between the next to the last body and the last one than between the first and second bodies. For this reason the heating surface of the first bodies is not reduced to make up for the smaller difference in temperature. In cases where vapor is taken for heating juice, the heating surface of the first body, on the contrary, is made larger than the other ones. This provides for a greater fluctuation in the steam consumption of the heaters. However, it is surprising how much heat can be drawn from the first bodies of the evaporators even without increasing their heating surface. There are evaporator stations working with increasing heating surfaces from the first bodies to the thick juice bodies, and even from these first bodies vapor is taken for heating purposes. The heat transmission coefficients for the standard vertical and

Wellner and Jelinek evaporators are, according to Claassen, for a quadruple effect:

First body	40–50
Second body	30–40
Third body	20–30
Fourth body	10–15

For a triple effect:

First body	40–50
Second body	30–35
Third body	12–15

A factory of 1000 long tons capacity having quadruple evaporators, from which no steam is taken away for heating services, has to evaporate about 1120 tons of water, or about 280 long tons of water in each evaporator which represents approximately 151,200,000 calories, not counting the heat which might be transmitted through the heating surface by the small difference in temperature of the boiling juice and the condensed water on the two sides of the heating surface. This means, in one minute, 105,000 calories, or assuming a drop in temperature of 20° C. from the third to the fourth evaporator, and taking the heat transmission coefficient as low as 10, $105{,}000 \div 20 \times 10 = 525$ square meters of heating surface. With equal heating surfaces and with a heat transmission coefficient of 20 in the third body, the temperature difference between the second and third body will be 10°.

With equal heating surfaces and with a heat transmission coefficient of 30 for the second body, the temperature difference between the second and first evaporator would be about 8° C. and the exhaust steam would be 6° higher, so that an evaporation under these conditions could be represented in the first table on the next page.

These coefficients are put low; but an allowance should be made for incrustations, etc.

For a factory in which the diffusion battery and the diffusion juice are heated by vapor from the first body of the

	Heating Surface, Sq. Meter.	TEMPERATURE.		Heat Trans. Coeff.	Difference of Temp. in Heating and Juice Chamber.
		Heating Chamber.	Juice Chamber.		
First body......	525	102° C.	97° C.	40	5
Second body....	525	97° C.	90° C.	30	7
Third body.....	525	90° C.	80° C.	20	10
Fourth body....	525	80° C.	60° C.	10	20

evaporators, the calculation will be different. Assuming the diffusion juice to be 125 per cent on beets, the pulp water 125 per cent on beets, the diffusion water going to the battery at 40° C., the pulp and pulp water leaving the battery at 50° C., the diffusion juice leaving the battery at 40° C., and the beets coming to the battery at 0° C., we have to heat:

Going to battery:	
1,000,000 kg. beets at zero	
2,500,000 kg. D. water at 40° C.	100,000,000 cal.
Coming from battery:	
1,000,000 kg. pulp at 50° C.	50,000,000
1,250,000 kg. P. W. at 50° C.	62,500,000
1,250,000 kg. D. juice at 40° C.	50,000,000
	162,500,000

of which 62,500,000 calories are used for battery work. To do this heating 116,000 kg. of steam are required, or 11.6 per cent on beets. To heat the diffusion juice from 40 to 80°, 50,000,000 calories or 90,750 kg. of steam, are required, again disregarding the difference in temperature of the condensed water and the heated juice and taking the specific heat of beets and juice equal to the specific heat of water. Altogether

For the diffusion battery	116,000 kg. =	11.6%
For the diffusion juice	90,750 kg. =	9.1
together		20.7%

The water to be evaporated from 1000 long tons of beets is

1120 long tons
minus 207 long tons
913 long tons in four bodies,

or 228 long tons in one of the three last bodies, or 85,500 calories per minute and 228+207=435 long tons, or 163, 125 calories per minute in the first body. Taking the same heat transmission coefficient and the same drop in temperature as in the previous calculation, we have 427.5 square meters in the last body, 427.5 square meters in the third and second evaporators, and 812 square meters in the first body, allowing only 5° difference between exhaust steam and first vapor. With greater difference here or with a little higher pressure in the exhaust steam line, we should be able to reduce this heating surface considerably, on account of having three or four times as high a coefficient of the heat transmission here as in the thick juice body.

The steam consumption in the two cases under consideration is approximately as follows, as far as evaporation and heating is concerned:

Case I, in twenty-four hours, exhaust steam or live steam in evaporators	280,000 kg.
Heating battery and diffusion juice on exhaust and live steam	207,000
	487,000
In case II, in twenty-four hours.	
In first evaporator exhaust and live steam	435,000 kg.

That means a net saving of 52,000 kg. or 12.5 per cent of steam and consequently of coal, calculated on the coal needed for the evaporation and heating in a factory which uses vapors from the first body of a quadruple effect for heating battery and diffusion juice.

Other stations in the house where vapor from the evaporators can be used include the heaters between first presses and second carbonation, the thin juice heaters, etc.

All these arrangement materially increase the capacity of the evaporators and the coal economy. Furthermore, quintuple evaporators are more economical than quadruple effects and vapor may be taken from their second body, thus further reducing the amount of water to be evaporated. A calculation of a quintuple effect with heaters follows:

			Tons
Water to be evaporated from 1000 long tons of beets			1120
Heat needed at diffusion battery	116,000 kg. steam		
Vapor from second body of quintuple		232	
Heat needed for heating diffusion juices	90,750 kg. steam		
Vapor from second body of quintuple		181	
Heat needed to heat juice after first carb. and before evaporators, together 15° C.	34,035 kg. steam		
Vapor taken from first body of quintuple		34	
		447	
There remain to be evaporated in quintuple effect			673
or 135 tons per body			

	Tons of steam
For heating the battery there is required in first body of evaporators	116
For heating diffusion juice	90.75
For heating thin juices	34
	240.75
For evaporating 135 tons of water per body	135
Total steam needed in evaporators	376

against 435 tons of steam in a quadruple with partial heating and 487 tons of steam in a quadruple effect without using vapors for heating purposes, but heating diffusion battery and diffusion juice by live or exhaust steam.

The heating surface of the juice heaters can be figured in the same way, taking a high heat transmission coefficient, say 40. This heat transmission coefficient for the heaters varies with the velocity with which the juice passes through the bundles of heating tubes, 250 square meters for the diffusion juice heaters and 200 square meters for the thin juice heaters would be sufficient for a house of 1000 long tons of beets. This is ample and allows for cleaning out, which has to be done frequently, especially with the diffusion juice heaters, caustic soda being the cleaning material.

All these calculations are rough, using round numbers everywhere, disregarding losses of heat by radiation, taking average figures for the temperature at the battery and leaving out of consideration the influence of the heat of the condensed water on the heat of the boiling and heated material at the other side of the tubes, taking 540 as the latent heat of the steam, etc. Rough factory calculations may be made in this way. In making such calculations it is always advisable to be on the safe side, to put the coefficients low, and allow a little leeway for the practical design.

The vapor from the last body of an evaporator system goes to a condenser and is there condensed with cold water. The amount of cold water to be used in the condenser is approximately determined as follows: 540 plus the difference between the temperature of the water coming from the condenser and that of the vapor is divided by the difference between the temperatures of the water going to the condenser and the water coming from the condenser. For instance, if the water going to the condensers is 20° C. and the water coming from the condensers 40° C. the difference is 20 calories per kg. The vapor from the last body may be 60° C., then 1 kg. of vapor gives 540 calories of latent heat. The condensed water is 40° C., so 20 more calories are freed or $540+20=560$. These 560 calories heat x kg. of water 20° or $x=\frac{560}{20}=28$ kg. of water necessary to condense 1 kg. of steam at 60° C. Therefore:

In the case of a quadruple effect without heaters: 1,000,000 kg. of beets, in twenty-four hours, give 280,000 kg. of vapor in the last body, requiring 7,840 cb.m. of water in twenty-four hours.

In case of a quadruple effect, heating the battery and diffusion juice from first body: 1,000,000 kg. of beets give 228,000 kg. of vapor in the last body requiring 6,384 cb.m. of water in twenty-four hours.

In case of a quintuple effect, heating the battery and diffusion juice from second body and thin juice from first body: 1,000,000 kg. of beets give 135,000 kg. of vapor in the last body, requiring 3780 cb.m. of water.

The condensers used in beet-sugar factories are variously constructed. In some of them the vapor and water travel in the same direction, while in others, the vapor goes in the opposite direction to that of the falling water. Detailed description of the different types of condensers will be omitted here, but, on the other hand some general suggestions will be made in this chapter. The passage of the vapor in the condenser should, by all means, be as free as possible. The condenser not only receives the vapor from the last body but the ammonia and carbonic acid gases of all the bodies. All of these gases go to the condenser and there meet water which is often rich in lime salts. The lime salts are precipitated and deposited on the surface of the condenser and, if there are small passages through which the vapor has to pass, the incrustation may be sufficient to hinder its passage. Grates or perforated sheets should be avoided, and the condensers and the condensed water pipe should be cleaned after each campaign. Another disturbance often occurs where the cold water is introduced into the condenser by means of perforated pipes which often become clogged with leaves and other impurities, hence it is preferable to have the water enter freely and flow against a shield.

The old cascade condensers are about the best ones in use. They cannot be clogged by incrustation and they are efficient and simple in construction.

CHAPTER XI

THICK JUICE SATURATION AND FILTRATION

THE thick juice comes from the evaporators at a density of about 60 Brix and a temperature of about 60 to 65° C. In the evaporators not only the sugar, but the non-sugars as well have become more concentrated. In regard to the latter, the concentration has become so great as to precipitate part of the non-sugar substances. Thick juice from the evaporator appears cloudy, which means that the evaporators have not only eliminated the water, but have also participated in the after-purification of the juices. When this juice is heated, an additional amount of non-sugar substance is precipitated and, therefore, a good heating of the thick juice at this point is of great importance.

A high temperature not only precipitates more of the non-sugars, but gives a precipitate which is more crystalline, and in a better condition to be filtered. A high temperature decreases the viscosity of the thick liquor and makes it, for that reason, easier to filter, thence, the thick liquor of the evaporators should, by all means, be heated and, since the temperature of the thick juice from the evaporators is considerably lower than that of the vapors of the first body the first part of this heating ought to be done by vapor in reheaters.

The thick-juice pump is most effectively located on the ground floor of the factory, so that the weight of the liquor in the suction pipe helps the pump to overcome the high vacuum in the last body. A small receiver near the pump in this suction line, connected by a small $\frac{1}{2}$-inch air pipe to the vapor space above the thick juice, is found advantageous in helping the pump regain the suction, after the outlet valve of the thick juice has been shut off for any length of time. In the regular operation of the factory this valve should be regulated so that the juice is drawn off continuously—a thing to be desired with all the other juice valves of the evaporators, so that the juice flows in, through, and out of the evaporators in a continuous stream. In old factories with regular work this is quite possible. Only in case of interruptions should the valves at the evaporators be changed according to the conditions, and in such cases the thick juice pump is apt to lose its suction. The receiver mentioned helps the pump in such cases. From the thick juice pump the juice should go through heaters, as stated above to the blow-ups. These blow-ups must have heating coils heated by live or exhaust steam with enough heating surface to heat up the juice almost to the boiling-point. Some factories blow in live steam at this station, which, of course, thins down the juice unnecessarily.

The thick juice from the evaporators is very variable in its alkalinity. From normal juices, which are treated as described in the chapter on After-Purification, an alkalinity of 0.05 to .10 may be expected, which has to be reduced by saturation, and here sulphurous gas is generally used with good success. Sulphurous acid is to be preferred to carbonic gas on account of its bleaching qualities. There is a conflict of opinion as to the correct amount of alkalinity of the thick juice, some prefer a higher alkalinity, some neutrality. We might say that neutrality is always dangerous and a small alkalinity is under all circumstances more advisable. In modern factories with second product crystallizers, the whole process of recovering the last sugar by crystallization from a certain amount of beets will not take more than a week. In factories with hot rooms and fillmass tanks, the process of recovering the sugar by crystallization may extend over months. In the former case the alkalinity of the saturated thick juice may be kept lower, about 0.01 to 0.02, while in the latter case it will be advisable to keep the alkalinity as high as 0.02 to 0.03.

The sulphur stoves used in the thick juice saturation are the same as in the thin-juice sulphur station and have already been described. The same remarks about the difficulties regarding sulphur valves and steam connections to sulphur pipes apply here, too. Some factories have a continuous thick-juice sulphur station and use for this purpose one single tank into which the thick juice is pumped continuously. An overflow takes the juice to the thick-juice filter station, the juice as it passes through this tank, being heated and saturated. Such an installation is simple and quite satisfactory.

Difficulties are likely to occur at the thick-juice sulphur station, if juice from fermented beets is worked. In this case the thick juice from the evaporators may be neutral or acid, even if the thin juice was decidedly alkaline. In such cases the juice ought to be given a slight alkalinity with milk of lime. Some factories add soda ash to the juice, but the criticisms made in the chapter on After-Purification apply here as well. Normal juices from good beets, properly treated in the diffusion battery and in the purification, do not need the addition of soda ash; and it is very questionable whether juices from fermented or unripe beets, containing much lime combined with certain known and unknown organic substances, can be bettered by replacing the lime by sodium.

In rare cases where there have been long interruptions or where a new factory has been delayed in construction, the fermentation of the beets may reach such a state that it is impossible to make white sugar. The only remedy for this condition is to make brown sugar and melt it up again. In such cases losses are unavoidable. All the different fillmasses crystallize much more slowly and delay the work, making the juices in the diffusion battery so much the worse. In such cases it may be advisable to boil raw sugars and melt them up later, in order to give the full pan capacity to the boiling of raw sugar and, by working as quickly as possible, to reduce the losses to the lowest possible point.

In such cases the greatest care has to be taken at the diffusion battery in order to extract the smallest possible amount of those objectionable substances which the lime purification can remove only partly, or not at all. Treatment of the thick juice with chemicals, such as phosphate, certainly would not help in cases like these, which luckily do not occur very often.

From the thick-juice sulphur station the heated and saturated thick juice is sent to filters for the last filtration before the vacuum pan. The importance of this filter station cannot be too strongly emphasized. It is absolutely necessary to send the thick juice to the pans in as clean and sparkling a condition as possible. The color of the juice is far less important than its clearness. The crystallization of any substance begins wherever a favorable starting point presents itself. If the juice is cloudy, that is, if it contains foreign particles in suspension, the sugar will begin to crystallize around these particles; and thus a foreign particle will be enveloped and embodied in the sugar crystal, so that it cannot be washed away. Such sugar can never be washed white and therefore first-class sugar can never result from cloudy thick juice, and for this reason many factories have a double thick-juice filtration, which is very desirable.

The types of apparatus used for filtering thick juice include filter presses, closed daneks, and many other machines of varying construction. For a second filtration, sand filters have proved to be most satisfactory. The thick-juice filter presses are generally very simple, without sweet-water channels and with very thin frames, because there is seldom a substantial cake in them. The pressure used for filtering the liquor through them is about 2 to 3 m., presses being generally installed underneath the thick juice sulphur tanks. The same is true of the closed daneks, which differ from the open daneks only in having a tight cover to allow a greater pressure on the liquor. The frames of the filter presses must be provided with cocks which can be shut whenever a frame runs cloudy; and, for the daneks, wooden plugs must be kept ready to shut off a cloudy bag, If the thick-juice saturation is conducted intermittently, that is, with two or more tanks, which are saturated alternately care should be taken at the filter press or danek station to see that the volume of juice passing through the station is kept reasonably constant. The valves of the filters should be opened just far enough to complete the filtration during the time available for it. The more slowly the filtration is conducted, the more efficient it will be. It is customary in some factories to send thin juice from the sulphur station through a newly opened filter. In about an hour the filter cloth becomes coated with lime salts and a better filtration of the thick juice is thereby insured. With such an arrangement it is possible, after a filter has been used for thick juice and requires cleaning to repeat the thin-juice filtration and thus reduce the sugar content of the mud. This washing with thin juice, however, should be done carefully and continued only until the thick juice is replaced by thin, otherwise the precipitated impurities go into solution again.

For a second filtration the sand filter seems to be growing more and more popular. Some forms of the latter allow a washing of the sand in the filter itself; other types have to be emptied, and refilled after the sand has been washed.

The great importance of having all the liquors going to the first pans as clear as possible has led the majority of factories to combine with the thick-juice blow-up and filter-stations a similar station for melted sugar and for the wash syrup. The melted sugar of the second fillmass usually has a density of 60 Brix. It is heated almost to the boiling-point in the melted sugar blow-up and filtered through filters similar to those used for the thick juice.

In most factories the melted sugar is pumped into the thick juice blow-ups and runs, together with the thick juice, through this station and the subsequent filtration. Some factories pump the melted sugar back into the second carbonation to give it the benefit of another lime purification,—

a proceeding absolutely unnecessary, unless the purification in the first carbonation from previous operations has been faulty. The greatest disadvantage of this proceeding, however, is an unnecessary tax on the evaporators on account of the concentration of the thin juice. The evaporators have to eliminate the same amount of water in either case; but when melted sugar is added they have to work upon more concentrated juices, that is to say, with a lower heat transmission coefficient and therefore a reduced capacity of the evaporators.

The high-wash syrup is thinned down, when necessary, to the same density, heated almost to the boiling-point and then filtered, either through the same kind of filters as the two other liquors or in the bag filters which are used in some factories for this particular liquor.

Some factories send the high-wash syrup to the thick juice blow-ups and have only one high pan liquor. There is not much objection to this practice, since the thick juice and the high-wash syrup are about equal in purity.

A high temperature in all of these liquors facilitates the filtration to a considerable extent.

CHAPTER XII

FIRST FILLMASS AND REMELT SUGARS

The saturated and filtered thick juice is further concentrated and boiled to grain in the vacuum pans, which are either vertical cylinders with conical bottoms or Wellner Jelinek pans. The size of the pan should be so adapted to the capacity of the house that there are two pans for the first product, thus relieving the boiler house considerably, by securing a more even consumption of steam. In the vertical cylinder type of vacuum pan which is most commonly used, the heating surface is generally arranged in coils, usually of copper.

It is best to have these coils connected with separate traps, because a common trap necessitates the use of check valves which often leak and cause steam to back into the upper coils before they are covered. They thus burn sugar, and, if the coils fill up with water and steam is opened, they are liable to break. They have to have enough heating surface to concentrate the thick juice quickly so as not to lose too much time in concentration; and, on the other hand, they must be arranged in such a way that they offer the least resistance to the circulation of the fillmass. For helping the circulation of the fillmass, which is slowest, of course, toward the end of the concentration, when it should be heavy, some pans, especially the Wellner Jelinek, have mechanical agitators.

To increase the circulation of the fillmass Claassen introduces steam into the lower part of the fillmass, through the charging line of the liquor. This steam passes through the fillmass and mixes it better than any mechanical arrangement.

The material used for the vacuum pans was formerly copper, but lately the expensive copper has been replaced by cast iron. Wrought iron is inadmissable, as it oxidizes and contaminates the fillmass and consequently the sugar with black spots of iron oxide.

The pans require a series of sight glasses in front of the apparatus and these have to be kept clean, so that the sugar boiler has his fillmass before his eyes at every moment. To keep these sight glasses clean there are small perforated pipes directly behind them, through which steam is blown to melt away the residue of fillmass which adheres to the windows after a pan is emptied. Furthermore, there should be sight glasses for illuminating the interior of the pan. To facilitate further control each pan is provided with a proof stick, by which samples can be taken during the boiling. They must reach far enough into the fillmass and must be in locations where the fillmass is circulating, so as to get as fair an average sample as possible.

Sometimes the juice foams, especially if it is from fermented beets, or if irregularities in the vacuum occur, and in that event the addition of a little oil is of assistance. Hence, each vacuum pan has a butter valve through which oil can be introduced into the interior. Each pan has a thermometer and a vacuummeter. For the latter, mercury manometers are preferable, as they are more accurate. The thermometer must project far enough into the fillmass to give an accurate average reading for the temperature. A recording thermometer, which allows the superintendent to watch the temperature of the whole strike, is of great importance. With such an instrument the sugar boiler can be controlled far better than without it. If there is, in addition to a mercury manometer, a recording vacuummeter, the whole work of the sugar boiler can be followed and controlled.

The charging pipe of the pan has to be wide enough to enable the sugar boiler to loosen up the grain in a short time, if for any reason his fillmass has become too concentrated. The charging valve must be directly in front of the pan, handy for the sugar boiler. The charging pipe goes down to the lowest part of the pan, where it often ends in a perforated piece, distributing the juice in fine streams into the lower part of the fillmass, whence it rises, owing to its lower specific gravity, all through the fillmass.

The vapor from the pans generally goes through a juice catcher to the condenser and each pan usually has its own condenser and its own vacuum pump. The vacuum can be reduced in this way by gradually closing the water valve of the condenser and thus any vacuum which is necessary can be maintained in the pan. On account of their viscosity, beet-sugar juices must not be boiled at the highest possible vacuum, but at a high temperature.

There are other arrangements used in sugar factories such as connecting several pans with one condenser or connecting several pans, each provided with a condenser, with one vacuum pump, or even having one central condenser for evaporators and vacuum pans.

The advantages and disadvantages of these different arrangements are treated in the chapter entitled "Miscellaneous" under the head of "Centralization of Condensers and Vacuum Pumps." For the present we shall only point out the necessity of being able to increase and decrease the vacuum at will. This is most easily done in a pan connected with its own condenser and its own vacuum pump.

The outlets of the pans are generally 20-inch valves, or even larger ones, with hydraulic rubber rings or other packing, or planed slide valves. These valves have to be cleaned carefully and steamed off after a strike is dropped, so that they shut air-tight for the next strike. After each strike the whole pan has to be steamed to eliminate the fillmass remaining on the coils and in the different corners, sight glasses, etc., otherwise the grain remaining in the pan will go into the next strike. It will not be melted in the thick liquor which is quickly concentrated to the saturation point, and it will grow and give rise to very uneven grain in the next pan. For that reason steam connections have to be provided for the pans, and the steam outlets should blow directly against the places, where fillmass residue is apt to stay.

The thin steamings are let down either to the mixers or to the crystallizers, with the fillmass. This is especially done where the fillmasses are boiled to a very high concentration. Here the steamings serve to thin down the fillmass, which otherwise might become too thick to be worked; otherwise the steamings go to places of similar purity, for instance, the steamings of first pans to the melter, and the steamings of the second fillmasses to the green syrup tanks. Furthermore, many pans are equipped with cold or hot water lines, water being introduced into the pans only in cases of emergency, if, for example, a strike is found to be full of false grain. If the concentration and temperature of the thick liquor, melted sugar, and high syrups are kept right, and if steam pressure and vacuum are kept even, emergencies demanding the use of water ought not to occur.

The size of the heating surface in a pan is very variable. Formerly the aim was to have as large a heating surface in the pans as possible, but this interferes somewhat with the free passage of the fillmass in the pan; and the results in such a pan are inferior to those obtained with a smaller heating surface and a good circulation of the fillmass. Nowadays pans of from 30 to 60 long tons fillmass capacity have 80 to 160 $m.^2$ heating surface. This is large enough to insure a rapid concentration of the thick juice; and coils of this size leave room for a good circulation.

The thick juice coming from the thick-juice presses, after or without passing through an after-filtration, has a density of around 60° Brix. This juice is concentrated in the vacuum pans.

If a pure sugar solution is concentrated and allowed to crystallize at ordinary temperature the sugar will crystallize and the remaining liquor will have a density of about 66° Brix., the liquor keeping in solution 66 per cent of sugar. This liquor is then saturated with sugar. In other words, at ordinary temperature 34 parts of water will hold in solution 66 parts of sugar. The crystallization, however, does not take place instantaneously, but gradually; and so there is more sugar in the solution than in the saturated solution. The liquor has been supersaturated. The figure which indicates how many times more sugar is in solution at a certain temperature than there is in the saturated solution containing the same amount of water at the same temperature is called the supersaturation coefficient—a factor of fundamental importance during the whole process of boiling. Only if the supersaturation is kept in the right limits will the process of boiling proceed under the most favorable conditions.

For starting a pan, juice is drawn in to such an amount that, after concentrating it, the pan is about one-third full, more or less. On concentrating the thick juice, it soon passes the saturation point and becomes supersaturated. Then a drop of the liquor held between two fingers, pulls out into strings on opening the fingers. Steam bubbles stick to the sight glasses and assume a longitudinal shape with a sharp lower point when rising, and finally small crystals appear in the liquor. The sugar boiler has to judge when he has enough grain in the pan and stop the concentration at this point by taking in new liquor.

In this method of working the supersaturation coefficient is very high, perhaps as high as 1.5 ~~to 1.6~~, and the supersaturation varies with the time used for the concentration of the juice. Another method of graining a strike, is not to wait till the supersaturation is so high that the grain comes of itself, but to form the grain by giving the liquor a heavy mechanical movement, which may be done by taking in a very small, short charge of thick juice when the supersaturation coefficient of the liquor is around 1.3. This is the practice which is generally followed in Germany. One short charge does not generally produce enough grain, and the operation has to be repeated several times. The sugar boiler soon finds out how often and how long he has to charge, to make enough grain in his fillmass. For building a small-sized grain he has to repeat the foregoing operation oftener and he prefers to take a larger amount of thick juice into his pan at the start. The supersaturation can be higher than it would be for making a large-sized grain.

During the period of forming the grain, the boiling process has to be slowed down to prevent too high a supersaturation and the forming of undesired grain. The liquor surrounding the growing crystals has almost the same purity as the original thick juice, and so it must be given time to crystallize around the existing crystals without forming new ones. When the crystals have gained the desired character, the fillmass has to be thinned down, and for this purpose a large charge of thick juice is taken in to the pan. In this way the supersaturation coefficient is perceptibly lowered; and it must be kept low, that is under 1.2, till the final concentration of the fillmass begins.

In order to slow down the concentration during the formation of the grain very little steam must be used. But, at the same time, the temperature of the fillmass in the pan has to be kept high by reducing the water to the condenser. By this procedure two desirable effects are obtained at the same time; first, the supersaturation is kept low enough to prevent undesired grain from being formed and only this existing grain grows; second, the high temperature decreases the viscosity of the liquor. It seems that the viscosity of the liquor has a great influence on the formation of the crystals and it has been demonstrated beyond doubt that the higher the temperature is, during the graining process, the sharper are the crystals, and the more sparkle and brilliancy they have.

The grain formed at a high temperature consists of more individual, better-formed crystals, few twins or conglomerates of crystals being formed. Such grain, consisting of well-formed individual crystals, washes more easily in the centrifugals than grain formed at a lower temperature. The graining process therefore ought to be carried out at a high temperature. Between 76° to 80° C. might be considered a proper temperature for forming the grain. For sugar of such high gloss as loaf and domino sugar, a temperature of about 90° C. is used. After the grain is formed and the fillmass is thinned down, the thick juice is drawn into the pan either continuously or intermittently. In charging the juice continuously a supersaturation of about 1.1 should be aimed at, whereas an intermittent charging necessitates a fluctuation of the super-saturation coefficient from 1.2 to about 1.0. An especially large amount of juice should be taken into the pan the first time after the formation of the grain, when there is danger that the syrup will be too highly saturated and that undesirable grain will be formed. Later, when the concentration of the fillmass is almost completed, the purity of the syrup is considerably lower; and then a higher supersaturation not only does no harm but is, on the contrary, desirable, because less time is required for the crystallization of the sugar from a syrup of 90 purity and supersaturation coefficient of 1.3 than from a syrup of 80 purity and the same degree of supersaturation.

The concentration of the fillmass at the end of the boiling process naturally goes slowly and should not be pushed, because syrups of a lower purity need some time to crystallize. A cutting down of this time naturally results in a smaller yield of sugar from the fillmass. At this time a high temperature of the fillmass is also of great importance.

A fillmass with 7 per cent of water at 70° C. is so hard and thick as to be difficult to discharge from the pan, whereas a fillmass of the same amount of water at 90° C. flows out of the pan without offering the slightest resistance. With a higher temperature the viscosity of the syrup decreases, the fillmass remains more liquid, its circulation is far better, and, for that reason, the concentration is more successful, the resulting syrups are lower in purity, and the yield of sugar is larger. A temperature near 90° C. may be considered a suitable one for this last period of the boiling.

The time necessary to boil a strike of first fillmass is very variable. However, it is not always true that the faster a strike is boiled the better the work is done at the pan. Every sugar boiler is tempted to boil as quickly as possible, but this can be done only with a loss of yield in the first strike. The sugar needs some time to crystallize out, and the farther the desugarization by crystallization is carried the more time it requires. Furthermore, the time required for a strike depends upon the size of the grain. With a small grain there is a much larger surface upon which the sugar can crystallize than with a large grain. So a strike with fine granulated may take three to five hours, whereas a strike of coarse crystal sugar may require even eight to ten hours.

A fillmass of thick juice, melted sugar and wash syrup with a purity of about 89 to 91, may be boiled to give a green syrup of 79 to 82 purity. This is an undesirably high purity for the second fillmass, for, even if the wash liquor of the brown sugar is added to the second fillmass, the purity of this fillmass will be too high for proper extraction in one boiling from this purity to molasses, even with the modern crystallizers. Furthermore, a very high percentage of brown sugar will be returned to the process, and that is the reason why the modern factories try to get as much sugar out of the first fillmass as possible.

For that reason, these factories generally finish up their first fillmasses with high green syrup. It is self-evident that any fillmass, for which material of different purity is used, will start with the juice, of highest purity and take the other juices in the order of their purity. By taking at the end of the strike, the green syrup of the previous strike, it is possible to reduce the purity of the resulting syrup as low as 75, or even to 70, although such an extreme desugarization in the first fillmass would endanger the quality of the sugar. It is, however, perfectly practicable to attain a desugarization by crystallization in the first fillmasses, represented by a syrup purity of 75. Such a syrup can easily be boiled and exhausted in crystallizers to a syrup of molasses purity. It should be borne in mind that in a white-sugar factory all the liquors going to the first pan must be filtered. If green syrup is taken to the first pan this, too, must be filtered. If this is done the sugar crystallizes around the crystals already formed, and these are perfectly clear. If these crystals are formed and boiled as described above, they are easily washed. If syrup is added to the first fillmass, this fillmass ought to be concentrated, before adding the syrup, to as great an extent as possible. Then the syrup will thin down the fillmass again. The ensuing boiling is really a part of the crystallizer work, performed in the vacuum pan. By this procedure the whole work of the sugar end of the house can be done in two boilings and the installation is thereby reduced to a minimum. In white-sugar factories, which are the only kind established in this country, the brown sugar, resulting from the second fillmasses which are boiled out of the green syrups of the first fillmasses, is washed, melted, heated, and filtered, and then goes to the first fillmass.

Some factories do not wash their after-product sugar, but only spin it dry and melt the sugar in this condition. This practice must be regarded as a mistake, because there is a chance of eliminating low-purity material from the first fillmass. This low purity material goes into the first fillmass just before the grain is formed, which is a great deal more objectionable than taking lower purity syrup into the ready-boiled strike, as is usually done in finishing the first fillmass. If the raw sugar is washed properly a very high purity liquor results from the melted sugar. The wash syrup of the brown sugar, which may have a purity of 65 to 70, offers no objection, in so far as it is added to the second fillmass and has a tendency to lower the purity of this fillmass to the right degree, the purity of the high green syrup being usually too high.

In washing the after-product sugar to a high purity, a liquor is obtained in the form of melted sugar which is very near a pure sugar solution. This liquor is still more desirable than the thick juice for starting the strike and forming the grain. The only difference in the process of boiling and forming the grain with this liquor is that the supersaturation must be kept a little lower than with thick juice. With a well-filtered, high-purity, melted sugar liquor, the certainty of obtaining clear, white-sugar crystals is still greater than with thick liquor. Such a fillmass will be composed of melted sugar to which thick juice, then wash syrup, and finally green syrup has been added. Worked in this way, the original crystals are made of clear, high-purity material. When the grain is well grown and well formed, material of lower purity is gradually added, giving up its sugar to the sugar crystals and enlarging them. The syrups are pretty well exhausted and are fit to be boiled down in another operation, to raw sugar and molasses.

Most factories, however, prefer to mix the melted sugar with the thick juice, because in that way the sugar boiler has to deal with only one kind of first fillmass. It is decidedly wrong to send the melted sugar to any station of the thin juice-lime purification, because lime does not improve the purity of a material which has already passed the lime purification under proper conditions in a previous stage; and in mixing the melted sugar with the thin juices all control of the work of purification is lost, and an unnecessary tax on the capacity of the evaporators results.

The worst irregularity which can occur in the boiling process is the hard boiling repeatedly referred to in the previous chapters. This hard boiling occurs only if unripe or fermented beets are worked. The reason for the hard boiling is not fully known. It is most commonly attributed to the presence of lime salts, with acids which are derived from pectin substances, diluted in the diffusion process. A low temperature in the diffusion process, at which a minimum of these substances is dissolved, is the most effective means of overcoming this difficulty.

Glucose, i.e., invert sugar, which occurs to a higher degree in fermented beets, is decomposed with lime at higher temperatures, and forms lime salts. If healthy beets are available the fermented ones should not be worked alone, but should be mixed with good beets, in order to diminish as much as possible the objectionable influence of the substances which hinder the boiling and crystallization of the sugar. In many factories when cases of hard boiling occur soda ash is added in the thick juice blow-ups. In such juices the amount of lime in the form of salts is enormous, one-half of a per cent and even higher, but, according to Claassen, it is not necessary to add the corresponding amount of soda ash, but only one-fourth to one-half of it, because the objectionable lime salts, which are of high molecular weight, are first attacked by the soda ash. This recommendation involves the theory that the sodium salts of those obnoxious acids act less on the heat transmission and crystallization than the lime salts. Claassen recommends, furthermore, to give the fillmass a heavy circulation by blowing in steam through the charging line of the pan. The addition of a quart or two of oil sometimes helps in cases of slow boiling. In such cases sugar losses will be unavoidable, at least with our present knowledge of this difficulty; and it will be almost impossible to make white sugar out of such juices. But luckily, these cases are not of frequent occurrence and, with great care in storing the beets, excluding frozen beets and leaves as much as possible from the beet-storage piles, and watching the piles carefully for signs of fermentation, much can be done to avoid this unfortunate result.

Another irregularity in the boiling process is the appearance of black spots in the fillmass, making the sugar spotty. Such contamination consists of oxidized iron and occurs mostly in wrought-iron pans, and for this reason most of the pans are now made of cast iron. Yellow spots in the fillmass indicate that the pan has not been steamed out properly or that there are places where the fillmass is not in motion. Such fillmass burns hard on the coils and drops off after a while, getting into the centrifugals and keeping the sugar underneath these spots from being washed. In such cases, the steaming out arrangement should be looked over to make sure that no fillmass stays in the pan after the pan is steamed.

Small sugar losses may be caused by leaky coils. In this case the sugar can be detected in the special trap of the defective coil at the moment when the steam is turned into it. Sugar losses may be caused by entrainment in the pans; but such losses are generally small. Sudden changes in the vacuum, however, can produce a sudden evaporation and the steam rapidly generated can throw over a large amount of fillmass, though, as a rule, this will be caught in the juice catcher.

The purity of good thick juice from healthy beets, especially when mixed with high-purity melted sugar, is between 90 and 91. To boil down from this purity in one straight boiling operation may lead to a green syrup purity of 83. From this purity another straight boiling operation may lead to green syrups of 68 to 70, and a third boiling operation would be necessary to exhaust the juices to molasses. So there are really three boiling operations necessary to produce molasses. In practical work these three boiling operations are reduced to two. By taking in high green syrup at the end of the first strike, the purity of this fillmass is lowered to about 86 to 87; and from that purity it is possible to reach a green syrup purity of about 77. Again, by taking in low wash syrup at the end of the second fillmass, we can reach a fillmass purity of 75 to 76, from which a molasses purity of 60 or a little below may be obtained.

We have apparently only two boiling operations; but in reality we do the same amount of boiling by re-boiling part of the syrups. In fact we do more evaporating than would correspond to the foregoing three straight boiling operations, because we have to evaporate the water used to thin down the high wash syrup and high green syrup to melt their false grain and reduce their supersaturation so that they can be filtered. This water can be calculated by comparing the density of the corresponding machine and pan-tank syrups.

CHAPTER XIII

FURTHER OPERATIONS WITH THE FIRST FILLMASS

From the vacuum pans the fillmass was formerly dropped into small boxes (Schuetzenbachsche Kasten), where it cooled off quickly and a large amount of fine grain was formed. Such a fillmass could not be concentrated at as high a temperature as is possible with crystallizers. As this method of working is antiquated and has been abandoned in modern factories, it will not be discussed here.

Nowadays the first fillmass is dropped either into crystallizers, or into a mixer from which the fillmass is spun in the centrifugals directly after the strike comes down from the pan, thus making room for the next strike by the time it is boiled. The German factories generally adopt the first method and use open crystallizers. The American factories usually drop their first fillmass directly into one mixer, from which they spin the fillmass after it has been dropped. The efficiency of the crystallizers, however, is so great that we must not pass over them without some comment.

These crystallizers are long tanks, open at the top and provided with a round bottom and stirrers. Each crystallizer is capable of holding one strike and their number is from two to four for one vacuum pan; they are often provided with a double mantle. The idea of these crystallizers is to give the fillmass more time for crystallization. The syrup in a finished fillmass of small-sized granulated has a supersaturation of around 1.3. If this fillmass is given some time, sugar crystallizes upon the crystals which are present, enlarging them and decreasing the degree of supersaturation of the syrups. In cooling off, the supersaturation of the syrups increases again, and so the crystals continue to enlarge.

Such syrups can be desugarized easily to 73 to 75 purity. Care has to be taken that the cooling process does not take place too rapidly, because in that case the supersaturation of the syrups is likely to reach such a degree that undesirable grain is formed, and then the fillmass will be full of crystal flour which may be a serious hindrance to the work of spinning in the centrifugals. The syrups of a finished fillmass are, as a rule, so high in purity and have for that reason such a strong crystallizing capacity, that the natural cooling down of the fillmass in the crystallizers is sufficient to keep the supersaturation within the right limits. If, in an installation of this kind, crystal flour appears in the fillmass, the crystallizers have to be insulated. If crystal flour still appears, the crystallizers may be covered with wooden covers to prevent radiation of heat.

These first fillmass crystallizers have to be watched carefully. If the fillmass becomes too thick, filtered high green syrup should be added. The crystallizers are most efficient when they have a small independent engine or an auxiliary motor, to supply their power, because when their motion is interrupted the fillmass hardens very quickly. In such an installation, with a fillmass purity of 88 to 89 the purity of the green syrups can easily be reduced to 73 to 75.

The time which is necessary for such a desugarization will of course depend largely upon the size of the sugar crystals, a fine granulated offering a much larger surface for crystallization than a coarse crystal sugar. A fillmass with fine grain will therefore exhaust the syrups much sooner than one with large grain.

When only one mixer is used, the benefit of this after-crystallization is lost and consequently the purity of the green syrup is higher and the yield of granulated from the first strike is lower. However, the influence of the after-crystallization even in the mixer can be plainly demonstrated by testing a sample of green syrup from the centrifugal at the very beginning of the spinning and at the end of the strike. Differences of 1 to 2° in purity are common occurrences. From the crystallizers or mixers the fillmass is transported to the centrifugals. When mixers are used the centrifugals are generally fed by spouts. From first product crystallizers the fillmass either goes in screw conveyors to the centrifugals into which it is discharged by similar spouts, or it is emptied into little cars, which are suspended by rails, and is dumped from these cars into the centrifugals. Screws and spouts give cleaner work, but the amount of fillmass has to be estimated by the operator. With wagons, a certain definite amount is dumped to each machine. After some practice, however, in filling from spouts, the operators of the centrifugals get enough experience to charge the centrifugals with approximately the same amount of fillmass.

The centrifugals consist of cylindrical perforated baskets which revolve at a high speed, 1000 to 1200 revolutions per minute, depending on the diameter of the drum; and here the separation of the sugar crystals from the syrup is effected by centrifugal force. The baskets are of different sizes. Formerly a diameter of 800 mm. was standard; nowadays they are built larger, 900 to 1000 mm., or more in diameter, larger machines effecting a considerable economy of hand labor. The baskets are perforated cylinders made of the strongest material, because they are exposed to a heavy strain when revolving at high speed. Bronze or cast steel is the material used. The holes in the mantle are 6 to 10 mm. in diameter; inside of this mantle another mantle of coarse woven wire is fastened, and inside of this wire cylinder the regular centrifugal screen is placed. These screens vary greatly as to the size and shape of their holes. Some factories use woven sieves; in most factories, however, perforated sheets are used. The holes are sometimes conical, having the smaller end inside of the centrifugal machine so as to insure a free passage of the syrups and small crystals when they have once passed the smallest part of the hole.

The baskets are either driven from underneath, in which case the centrifugals stand on a foot pivot, or they are suspended and driven from above, this latter arrangement giving a freer bottom discharge for the sugar. They are driven by belts, electric motors, or turbine water motors, the belt-driven centrifugals being the most common type. They have the advantage over the water-driven centrifugals of using less steam than is required by the direct-acting, high-pressure water pumps which are generally used to maintain the necessary water pressure. Moreover, the belt-driven centrifugals acquire the necessary speed in a shorter time than those driven by water; and this is very essential for the proper spinning of the fillmass which can be spun dry before it rises to the top of the centrifugals.

The revolving baskets of the centrifugals are surrounded by cast- or wrought-iron mantles, against which the syrups are thrown. The bottoms of the centrifugals gather these syrups and should be sufficiently inclined toward the outlet of the syrup to insure a rapid separation of the syrups of different purity. There are different devices to insure this rapid separation. Double bottoms, with holes which are opened or closed by a lever, rapidly discharge the syrup gathered in them. There is generally one outlet provided with a movable spout leading to two different gutters. The green syrup flows to one of these gutters and, as soon as the wash liquor is expected, the spout is turned over to the other gutter, which carries the wash liquor away to a separate tank. Such an installation requires some attention from the operator of the centrifugals; otherwise green syrup may flow to the wash syrup tank or vice versa. There are automatic devices which consist of different chambers the size of which can be varied. The green syrup fills the first chamber, the wash liquor the next and the last steamings may flow into a special gutter. These arrangements, of course, require that the filling of the centrifugals be uniform, which is more difficult to accomplish if the centrifugals are filled by means of spouts.

As a rule, the spinning of the sugar is a very simple operation and ought not to involve any difficulties; but if the fillmasses have a very uneven grain and much crystal flour, in consequence of a faulty handling of the pan, the centrifugals have to run a long time before the syrup is drained. The small crystals fill the spaces in the regular grain and form an impenetrable wall for the syrups. It is hard to remedy such defects in the centrifugals. The mistake has been made in a former station (the vacuum pan), and such sugars may not wash at all. It is better in such cases not to lose too much time, but to spin the sugars as dry as possible and send them to the melter to be boiled over again. Some centrifugals have a small steam connection between the outside mantle and the revolving basket. By blowing steam around the basket it is possible to melt some of this fine sugar and open a passage for the syrups; but it is not likely that first-class granulated will result from such a fillmass. If there is any doubt as to the quality of the sugar, it is better to go to the expense of melting it over again than to sell off colored sugar. All the centrifugals must have steam connections so that they can be cleaned occasionally by melting away the fine sugar flour which gathers between the screens. For this purpose steam hose is generally used. The steamings, of course, run into the wash syrup.

In this country almost all the beet-sugar factories produce granulated sugar, ready for the consumer, and raw sugar is not made to any extent. For that reason extended description of the production and handling of raw sugar is omitted, only remarking that raw sugar is not washed but spun more or less dry. Raw sugars have to be decidedly alkaline with phenolphthalein as indicator and must be cooled off before they go into piles if the sugar is expected to keep.

In order to make granulated, the sugar is washed in the centrifugals. Strictly speaking, this is not refined sugar, but is produced at the first strike without being melted and reboiled. Herein may be seen the most precise distinction between a beet-sugar factory making white sugar and a refinery, although the implied definition is not absolutely correct because all the after-product sugar produced in a beet-sugar factory is washed in the centrifugals melted and boiled in together with the thick juice. The larger proportion, however, of the granulated sugar from the first fillmasses is not melted and reboiled.

For washing the sugar in the centrifugals different liquors and means are used. Some factories wash first with thick liquor and afterward with water or steam. Some dissolve white sugar, or lumps of sugar, to make a wash liquor; they divide the wash liquor and use the latter part of this liquor for the first washing in the next operation.

The foregoing operations necessitate a little more complicated installation for separating the different liquors; and the small increase in yield from melting away less sugar may be offset by the complication of the machinery and the process.

Washing is commonly done either with steam or with water. For washing with steam, it is preferable that the centrifugals be driven from underneath, because they must be covered, and the steam used for this purpose must be well dried. Good effective water-catchers must be installed in this special steam line. The steam coming in contact with the sugar condenses on the surface of the sugar crystals and forms a kind of wash liquor, which replaces the green syrup and is driven out by the steam. The color of the last liquor running from the centrifugal indicates when the washing is finished; then the centrifugal machine has to be brought to a full stop before the steam valve is closed, otherwise the sugar gets hard. This latter effect is desired for some kinds of sugar such as Pilé or lump sugar. If this sugar is being made, the centrifugals are equipped with vertical wedge-shaped pieces which separate the ring of sugar into four segments. When, under these conditions, a centrifugal has been sufficiently washed, the steam is shut off and then the machine is stopped; the wedge-shaped pieces are taken out and the four hard segments can be removed; they are cooled off, broken in crushers, sacked and sent to the market under the name of Pilé.

The granulated sugar, washed by steam, is dumped from the centrifugals, transported by means of a shaking spout (in preference to a screw conveyor), lifted, bolted, and sacked. It is then ready for the market. On the way from the centrifugals to the bags it cools off and loses the last traces of humidity.

Sugar made from beets for direct consumption sometimes has a slight tinge of yellow and therefore, in former years, a small quantity of ultramarine was mixed with it. If the sugar is washed with steam in the manner above described, this ultramarine is not usually added in the centrifugals, but in the vacuum pan, at the time when the grain has been formed and the crystals are still small. The amount of ultramarine added to a pan of 40 tons of fillmass may be half a pound or less. This ultramarine has to be mixed properly, preferably with a little thick juice, till all the lumps are broken up. Part of the ultramarine grows into the crystals and gives the sugar a clean white color. The quality of the ultramarine is of great importance, and care must be taken in selecting it. Poor quality ultramarine makes discolored, or greenish sugar. The chemical composition of the ultramarine is not yet fully known; it is a double compound of aluminum-sodium silicate with polysulphides of sodium.

In this country the method of washing with water in the centrifugals is generally adopted and the ultramarine is added to the wash water. A large amount of the blue wash water is prepared and stirred by air or mechanical stirrers, to keep the ultramarine in suspension and to insure a uniform color and uniform conditions for at least one entire strike. Instead of ultramarine some factories use "Pearline," an aniline color, which goes into solution. This aniline color has to be treated with a little citric acid; otherwise a change of color might occur when the sugar is used in acid liquids such as lemonades. Ultramarine seems to be generally preferred for coloring the sugar.

The water is introduced into the centrifugals by means of hand cans, by which the necessary uniform amount of wash-water can be measured. The outlets of these cans are provided with sprinklers which must be bent into a convenient shape to enable the operator to reach and sprinkle the upper part of the centrifugal drum as well as the lower part. Otherwise, the upper part of the sugar, directly under the top of the centrifugal would remain unwashed and yellow and this yellow sugar, being mixed in with the well-washed white sugar, is likely to discolor the lot. The foreman of the centrifugals determines, at the beginning of a new strike, the necessary amount of water to be used on a machine, and instructs his men accordingly to perform the washing as uniformly as possible. This method of washing has given place of late to the use of mechanical sprayers some of which work satisfactorily.

By careful operation throughout the house, especially with good diffusion and first carbonation work, the application of bluing has become unnecessary. In fact, the above account of the use of ultramarine and Pearline is given mainly for its historical value, although even nowadays there is some beet sugar, as well as some cane sugar, which would not be the worse for a slight addition of bluing.

In later years the washing with cold water has been replaced by washing with warm water, which is far more effective, and permits a material reduction of the amount of wash water. The sugar resulting from this washing is, of course, wet, contains about 1½ to 2 per cent of water, and has to be dried, for which purpose granulators are used. The sugar is dumped from the centrifugals, by hand or mechanical sugar cutters, through bottom discharges, is transported by belts or screw conveyors to an elevator and lifted into the wet sugar bin, whence it is fed to the granulators, the latter being long revolving cylinders, mounted on an incline to insure the passage of the sugar to the lower end. At the upper end of the granulators a radiator is installed to heat the air which is drawn through the granulator by means of a suction fan. In addition, a closed drum, heated by steam, is often placed inside of the granulator. The sugar is lifted into the granulators by flights fastened to them, and it drops down, meeting the warm air, which removes the moisture from it. To avoid caking of the wet sugar at the sides of the granulator, heavy knockers keep the granulator in vibration. Often two granulators are arranged in series, one above the other, so that the sugar has to pass through both of them, the lower granulator in this case being used as a cooler. The air which is sucked through the granulators is usually discharged into dust collectors into which exhaust steam is blown to gather the sugar dust. Instead of the steam, thin juice is sometimes circulated through spray pipes.

It sometimes happens that the granulators become overheated, and in such cases the sparkle of the sugar suffers considerably and the sugar appears dull white without brilliancy. However, if the overheating of the granulator is the cause of this defect in the sugar, the lost sparkle often returns after a few days.

The granulators usually have coarse sieves at the end to sift the lumps out of the sugar. These lumps go back to the melter and the granulated dry sugar is elevated to the dry bin. Some factories have dry sugar bins which are large enough to store the sugar of one shift, thus enabling them to do all their sacking in the daytime and run the warehouse during the day only.

From the dry sugar bin the sugar is sacked and weighed either into barrels or bags. In recent years automatic scales for beet-sugar houses have replaced the common decimal scales, and the latter are used only to check the automatic scales.

For sacking the sugar, two bags are generally used, the outer bag being made of a coarse jute to protect the inner bag of finer cotton, which might be damaged in being piled. The sugar should be piled and stored in such a way that it is possible to count the bags, that is, in systematically piled lots of 500 or 1000 bags.

There are different mechanical devices for moving, piling, and elevating the sugar bags with a minimum of hand labor. None of these different schemes, however, is so far superior to the rest that a detailed description of them would be justified in this short handbook. Electrical trucks of fifty bags capacity, carrying the sugar over cement floors to electrical stackers, seem to be as good a device as any. It is desirable before closing this chapter to impress once more upon the reader the necessity of using the utmost vigilance and care at all the different stations, in order to make the sugar as good in quality as possible. We may mention, for example, the filtration of all the juices and liquors which go to the first pan, the work in the vacuum pan in graining and boiling, the washing of the sugar in the centrifugals, the proper drying of the sugar and cooling before piling the bags to prevent caking, etc. It does not cost any more money to make first-class sugar than it does to turn out poor sugar; and the beet-sugar factories in this country have to contend with a deeply settled prejudice of the public against beet-sugar, which is regarded by many as inferior to cane sugar.

If, for any reason, a lot of sugar proves to be a little inferior, it is better to remelt the sugar than to try to sell it. Even if such sugar is sold at a small sacrifice of money, with the declaration that it is a lower-class product, this declaration reaches only the larger dealer and is never known to the consumer, whose prejudice against beet sugar is thus increased. It is the consumer's prejudice with which we have to contend.

Another general remark might be inserted here, before closing this chapter; and that is to emphasize the necessity of having an independent pump for each liquor. It is false economy in the installation of a sugar factory to use the same pump for different liquors. Mixture of juices seems to be unavoidable whenever there is a possibility of mixing them.

CHAPTER XIV

AFTER-PRODUCT OPERATIONS

THE syrups resulting in the first product centrifugals are the green syrups, or the mother liquor by which the sugar crystals are surrounded, and the wash liquor. We have already spoken of the necessity of keeping these liquors well separated. The wash liquor has a variable purity, depending upon the purity of the green syrup and upon the facility with which the fillmass can be washed, which is represented by the amount of water needed for washing. The density of the wash syrup varies also. Usually this syrup has to be thinned down because it is supersaturated, especially when it has cooled. Some factories make a separation of the wash syrup and use the latter purer part of the syrup for the first washing in the next operation, though, as a rule, the whole of the wash syrup is taken to the next first-product pan. It is advisable to filter all the liquors which enter the first fillmass, and for filtering the wash syrup as well as the high green syrups, plate and frame presses, daneks, or bag filters can be used.

The green syrups coming from the first fillmass are, as a rule, pretty highly supersaturated, and this supersaturation increases as these syrups cool off in the succeeding manipulations. Furthermore all green syrups contain more or less crystal flour coming from the first fillmass. It is therefore necessary to thin down these syrups below the saturation point and to heat them; for this heating, open steam coils are to be recommended because there is no objection to the thinning of the liquors by heating.

If high green syrup is drawn into the first pan or added to the first crystallizers, this syrup must be filtered; and a filtration of the high green syrup going to the second fillmass might be recommended, because it tends to make the second sugar cleaner. The green syrup is boiled in vacuum pans of the same construction as the first pans, to a second fillmass. Sometimes calandria pans are used. These are pans with a different kind of heating chamber consisting of vertical or inclined tubes of large diameter, for fillmasses, which are boiled to grain in the vacuum pan, the pans with coils are in most common use. For boiling after-product fillmasses, steam of low pressure, such as exhaust steam, can be employed. Many factories even use the vapor of their juice boiler or first effect of the evaporators for this purpose. This is to be recommended, because these low-purity fillmasses have to be boiled slowly, to give the sugar an opportunity to crystallize; and, for that reason, only a little steam can be used at a time, so that even steam which is only at 100 to 110° C. allows the transmission of all the heat necessary for the concentration, if the heating surface is large enough and properly arranged (calandria type). Coils would not work for vapor on account of the uncondensable gases.

The second fillmass may be boiled in different ways. The old factories boil their after-products blank to hot-room tanks and have to repeat this operation two or three times until they reach syrups of molasses purity, because the first crystals which are formed soon sink to the bottom and do not give the syrup in the upper parts of the tanks an opportunity to crystallize around them. There are often differences of 4 to 6° in purity between the syrup above the sugar and the syrup between the sugar crystals, which is spun out in the centrifugals. No modern factory would install hot-room tanks, and this proceeding may be considered antiquated.

The modern factories use crystallizers almost exclusively for their after-products. By crystallization the sugar from the second fillmasses is exhausted in one operation and the syrups reduced to molasses purity. Even with crystallizers the boiling is conducted in various ways. Some factories boil the second fillmass blank to the crystallizers and add sugar crystals (preferably sugar powder) to start the crystallization, either in the pan before dumping the fillmass or in the crystallizers.

Most factories boil their second fillmasses to grain in the pan and drop the fillmass in that shape to the crystallizers. The latter way is the most common and gives the best results as to size of grain and final yield. We shall, therefore, give a more detailed description of this latter method than of the others mentioned.

Here again, as in the first fillmass a good crystallization depends largely upon the degree of supersaturation; but the conditions affecting crystallization are far more complicated in these low-product fillmasses than in the first fillmass. Whereas the supersaturation in clean melted sugar solutions and thick juice is practically that of pure sugar solution, in the second fillmass, and especially toward the end of the boiling the non-sugars increase considerably in proportion to the sugar and have a decided influence on the conditions of saturation, supersaturation, and crystallization. The influence of the non-sugars in low purity syrups on the solubility of sugar depends largely upon the temperature. According to Claassen, a syrup of 62 purity is saturrated with sugar at 20° C. if it contains 1.15 times as much sugar to one part of water as a pure sugar solution saturated at 20° C. At 70°, one part of water in a syrup of 62 purity keeps in solution 1.5 times as much sugar as the same amount of water in a pure saturated sugar solution at the same temperature. The figure which indicates how many times more sugar is contained in solution to one part of water in a saturated syrup than in a pure sugar solution at the same temperature is called by Claassen the saturation coefficient. This saturation coefficient is very much higher in warm syrup solutions than in cold solutions, and it is for this reason that many experts recommend adding water to the fillmass in the crystallizers when the temperature of the fillmasses goes down, in order to prevent too high a supersaturation of the resulting syrups. Too high a supersaturation causes a high viscosity of the syrups and this tends to prevent crystallization. The viscosity of the syrups is, however, still more influenced by the temperature, and is more or less destroyed by a high temperature. Therefore, these after-product fillmasses should be boiled hot. At a high temperature the supersaturation of the syrups can be carried higher than at lower temperature and thus the crystallization process can be shortened.

The boiling process in the second pan is more or less similar to the boiling process in the first fillmass. The purity of the high green syrup varies from 80 or 82 (from first fillmasses which have not been finished with high green syrup), down to 70. Although it would appear easier to exhaust a green syrup of 70 purity to molasses, this is not the case, because a syrup of 70 is not so easily boiled to grain as a higher purity syrup. On the other hand, syrups of 80 purity have to be boiled too thick to give all the sugar in one crystallization.

Practical experience has shown that a second fillmass of 74 to 76 purity can be most easily boiled to a good sharp grain in sufficient quantity to give enough crystal surface to exhaust the surrounding liquor to molasses in one crystallization. The first part of this crystallization is done in the pan. A syrup of 75 purity does not of course, grain so easily as thick juice; but it grains easily enough to be watched and regulated by the sugar boiler. The grain can be formed, as in the thick juice, by concentration to a high degree of supersaturation, or by giving the liquor a mechanical movement by drawing into the pan short charges of thinned, heated green syrup, though the time before the grain appears, is longer than with thick juice. The subsequent boiling is similar to the boiling of the first fillmass. After the grain is formed and well grown the fillmass is loosened up by taking a larger charge of green syrup, and then the point of supersaturation is kept lower by drawing in green syrup. In consequence of the higher viscosity of these syrups, the process of crystallizing proceeds very much more slowly than in the first fillmass; but if, during the boiling the fillmass is kept at a temperature of 80 to 90° C. the viscosity of the syrup can be considerably reduced, consequently shortening the time of the boiling.

The second fillmass is generally finished with a lower purity syrup; for this the wash syrup of the brown sugar which usually has a purity of 65 to 70, is taken. If the original green syrup has too high a purity to be lowered by the low wash syrup to 76, it may be advisable to draw molasses into the second fillmass at the end of the boiling to gain a purity of 74 to 76 in the ready-boiled fillmass.

For a good effect in the crystallization in the pan, ten to twelve hours will be necessary to carry the crystallization to a syrup purity of 65 to 67°.

The fillmass is then dropped to the crystallizers by means of closed pipes or open troughs, if the pans are at a higher level than the crystallizers. The open troughs are far superior to the closed pipes because they cannot become clogged, closed pipes having to be steamed out carefully after each strike is dropped. The ends of the closed pipes should be connected with the green syrup tanks for the purpose of steaming out.

The crystallizers are generally cylinders of a capacity of one pan, with a jacket for heating or cooling and slowly-moving stirrers inside, which make one revolution in three minutes.

In the crystallizers the fillmass should be kept from twelve to twenty-four hours at the temperature at which it has been dropped, in order to give the syrups time to decrease their degree of supersaturation. Then the temperature can be lowered about 10° per day. By this means the supersaturation of the syrups is again increased.

This increase is due directly to the lower temperature, and also to the fact that this lower temperature decreases the solvent effect of the non-sugars on the sugar.

The supersaturation of the syrups in the crystallizers may reach too high a degree, and cause crystal flour to be formed. The result is a high viscosity of the syrups which hinders the crystallization and makes it difficult to spin the fillmass in the centrifugals. This is the reason why many sugar experts recommend the addition of water to the fillmass in the crystallizers to keep the fillmass free, during the process of cooling. Thin molasses of the fillmass temperature has also been recommended for this purpose. When the temperature of the fillmass has reached the vicinity of 50° C. in three or four days, the fillmass is ready to be spun.

Other processes besides the one described are used in the sugar industry to crystallize the sugar in one operation from the green syrups to molasses, viz., the Huch crystallizers and the Grossé process.

The Huch crystallizers are similar to the ones described but are connected with a vacuum pump and can be used as vacuum pans with a very small heating surface, while the Grossé vacuum pan is, in its principle, nothing but a combination of a vacuum pan and crystallizer in one machine. The Grossé pan is provided with a central screw which moves the fillmass downward in the center of the pan, the results obtained with it being as good as with any ordinary pan and crystallizer, and may be obtained in a slightly shorter time.

The fillmass at around 50° C. is generally dropped to a mixer and from there spun out in centrifugals. It is a wise precaution not to fill the mixer above the reach of the paddles, so that water can be mixed with the fillmass if it is too sticky. We have already spoken in the previous chapter of the different ways of spinning the raw sugar. We shall repeat here that, for the regular run of the factory, the after-product sugar should be well washed and spun dry before being sent to the melter. The washing should be done with clean warm water. For melting the brown sugar, thin juice should be used. Highly washed sugars do not seem to keep very long, but are liable to fermentation. The last brown sugars which are obtained after the beets are cut and the production of white sugar is finished should either be spun dry without being washed, in which case special care must be taken that these sugars have a decided phenolphthalein alkalinity, or they should be thoroughly washed and sent to the granulators and dried. In this way a kind of "off-granulated" is made, which will keep until the next campaign and can be melted at the beginning of the next working period.

The centrifugals which are used for the after-products should be equipped with steam connections between the outside mantle and the revolving basket. The steam connections are for cleaning purposes and for use in cases of emergency, when they facilitate the spinning, if for any reason a badly spinning fillmass makes difficulties in the centrifugals. These after-product centrifugals should also be provided with movable spouts to separate the molasses from the wash liquor.

The low wash liquor is generally taken into the next second fillmass when the boiling of this fillmass is nearly finished, and the mother liquor has about the same purity as the wash liquor. The final product of this after-product centrifugal station is the molasses.

The term molasses is understood to indicate a syrup which does not yield any more sugar by crystallization after further concentration. This syrup cannot be purified by the common methods of purification used in an ordinary beet-sugar factory. A treatment with lime has no further purifying influence on molasses, unless the purification of the original juices from which the molasses results, has been carried on in a faulty way. Therefore all such proceedings as thinning the molasses and sending its solutions back to the carbonation with the intention of submitting the molasses for the second time to the purifying influence of lime are based on a mistaken idea and only bring non-sugars back to the first juices.

The amount of the molasses in a white-sugar factory is about 5 to 6 per cent of the beets with 2.5 to 3 per cent of sugar, so it certainly pays to save that amount of sugar, or the equivalent of it. There are different methods of accomplishing this purpose, feeding the molasses to stock being probably the simplest. In this way the potash salts of the molasses are added to the manure and returned to the farms.

Feeding with molasses and feeding with pulp can be economically combined. The value of the molasses as a food, however, varies with the agricultural and commercial conditions of different countries. Where food is cheap it will pay better to desugarize the molasses and recover the sugar by any of the different chemical processes which are used for this purpose. These processes are numerous; but only three of them, the Osmose process, the separation of the sugar in form of a lime-trisaccharate, called Steffen's separation, and the Strontium bisaccharate process have proved successful. The Strontium monosaccharate process has been tried on a large scale, but without success. The disadvantage of the Barium saccharate processes lies in the difficulties of regenerating the Barium oxide, and the same is the case with the lead saccharate process. The Strontium bisaccharate process is used only in Germany and there on a very large scale. This process may be the best of all in regard to yield and purity, etc., but it seems that its success in Europe is to be attributed to the commercial conditions existing there and to the historical development of the industry rather than to the real superiority of this process over the Calcium trisaccharate process. The latter may be combined so conveniently with the other operations of the factory, the saccharate serving at the same time to purify the juices, that this process is much preferable to any other. The only other process which has been adopted in this country is the Osmose process. The results obtained with the Osmose process are probably worse than those of any other process. However, it was the first one introduced into this country and this, perhaps, explains why it has been so widely adopted here. The Calcium trisaccharate process and the Osmose process being the only processes used in this country for desugarizing molasses, we shall confine ourselves, in the chapters which follow, to the description of these two processes.

CHAPTER XV

LIME KILN

One of the most important stations in a beet-sugar factory is the lime-kiln; and very strange ideas, regarding the work performed there, are often encountered.

The most common type of kiln is the Belgian kiln, which consists of two truncated cones joined at their large ends and suspended by columns, so that the lower outlet is entirely open. The kiln consists of an iron mantle into which a lining of firebrick is built. The firebrick of the upper cone leaves a free space of about 2 inches to be filled with an insulating material, cinders or clay being generally used for this purpose. The top of the kiln is closed with a cast-iron fitting and there is an arrangement for charging stone and coke into the kiln through a self-closing door. Great care must be taken to see that the top door of the kiln is closed as tightly as it possibly can be and that any cracks which appear there are stopped. Under the top door of the kiln is placed the suction pipe of the gas pump to pump out the gas produced in the kiln. Along the side of the kiln, sometimes in a spiral around it, there are holes through which the fire in the kiln can be watched and its contents broken down whenever arching occurs. These holes have to be kept closed to prevent air from being drawn into the wrong place in the kiln.

The other form of kiln in use in this country is not entirely open at the bottom, but has doors around the bottom through which the burned lime is withdrawn and the air for the burning of the lime enters. The iron doors, which are usually attached to these channels, should be taken away, because they do no good and may easily be misused. If they are not opened wide, not enough air will enter the kiln, carbon monoxide may be formed, and the pumps will take the air from wherever they can, through any holes or cracks in the kiln, from the top and from any leak that happens to be present. Such gas will contain much CO and also some oxygen which has been drawn in at the top and which meeting the cold gases, no longer combines with the carbon monoxide. If the kiln is tight, there is no possibility of drawing in more air than is drawn off by the pump. In case of a shut down of the factory, shutting down the gas pumps and carefully closing the kiln at the top will prevent any waste of material. If a shut down lasts for weeks the chimney which is always connected with any kiln should be opened for a few hours every day. This will keep the fire in the kiln from being smothered. Otherwise the two systems of kilns are alike.

The kilns are operated by mixing pieces of limestone from 5 to 6 inches in diameter with the necessary amount of coke. The amount of coke required is indicated by the condition of the burned lime and of the gas. The mixture of limestone and coke is elevated and charged into the kiln at the top door, which is generally constructed in such a way that it closes automatically as soon as a bucket is dumped. The weight of the limestone coming down a chute opens the doors.

The burned lime is withdrawn from the bottom of the kiln at intervals of from two to four hours. The oftener the lime is withdrawn, the more constant will be the movement of the kiln contents. This will minimize the danger of burning tight and bridging.

The chemical reaction taking place in the lime kiln is a dissociation of the limestone carbonate of lime, into burned lime, CaO, and carbon dioxide, CO_2, due to the heat produced by the burning of the coke which is mixed with the lime stone.

The two indications by which the running of the lime kiln may be regulated are the condition of the burned lime and the condition of the gas. If the lime is not burned through and there are many pieces with unburned rock in the center, an addition of coke is advisable. If the outside of the lime is slack and cindery, the amount of coke should be decreased. The dissociation of the lime and carbon dioxide begins at a little below 1000° C. The average temperature in the fire-zone of the kiln is from 1100 to 1300° C. At this temperature the pieces of limestone may be from 5 to 6 inches in diameter, as stated above. The necessary temperature varies according to the time the lime is exposed to the heat, and this time varies with the size of the lime kiln.

If the kiln is tight, so that there is no natural draft through it besides the draft produced by the gas pump, the latter regulates the work of the kiln. In the dissociation of limestone, 100 parts of limestone give 56 parts of burned lime and 44 parts of CO_2, assuming the limestone to be 100 per cent $CaCO_3$. If 10 per cent of coke of 85 per cent fixed carbon is necessary to burn the stone, another 31.2 parts of CO_2 result from the coke, that is, to say, 100 parts of limestone give 56 parts of CaO and 75.2 parts of CO_2. The carbonation of the same amount of lime requires only 44 parts of CO_2 or 58.5 per cent of the CO_2 available. In a good carbonation about 74 per cent of the gas is utilized so that only 60 out of 75 parts of available gas are used and 20 per cent are in excess. It is, therefore, possible to buy one-fifth of the required amount of burned lime and have enough gas to carbonate it. If the limestone has to be brought from a great distance there may be conditions under which it is cheaper to buy lime than to burn it.

If there is no lime bought the gas pump has to get rid of the surplus of gas. In this case the pressure at which the safety valve of the pump is set should be only a little higher than the tank pressure; and the pump must run fast enough to send this amount of gas to the air. The comparative independence of the size of the kilns is explained by the action of the gas pump on the kiln. The kiln is only the place where the lime is burned; the gas pump regulates the speed with which it is burned. For a certain house, with a certain per cent lime addition, a certain amount of gas must be pumped, to carbonate and burn the lime. This gas has to go through the kiln, which can burn only a corresponding amount of lime. In a large kiln the air current through the kiln is slower; the fire with less coke, is not so hot; and the lime stays longer in the kiln and in the fire-zone than in a smaller kiln. In a smaller kiln a higher percentage of coke is used, the fire is hotter, the combustion of the coke takes place more quickly and the lime remains for a shorter time at a greater heat.

Practical experience has shown that the diameter of the kiln should not be less than 2.5 m. and may better be 3 to 3.5 m., because the danger of arching of the burned lime in the kiln increases as the diameter of the kiln diminishes. In case of arching the only remedy is to push the lime down with iron bars through the holes of the kiln. Splashing water into the kiln is a risky thing and should not be done. A kiln of a diameter of 3 to 3.5 m., however, offers some protection against such arching. On the other hand, the diameter of the kiln should not be too large, because the filling of a kiln is never absolutely uniform and the air and gases going up through the kiln will naturally go through those places where there is the freest passage, especially in a large kiln. This means that in kilns which are too large there will be places through which little or no air will pass and where no burning will take place. Such an excessively large kiln is likely to burn in a one-sided and irregular manner, discharging unburned rock at one side and perhaps overburned rock at the other. Often an outside influence, like a steady draft through open doors in the kiln house, or radiation of heat from one kiln to another, where there are two kilns in operation, causes uneven burning in the kilns; and very large kilns respond more readily than smaller ones to such influences.

It is better to have medium-sized kilns and perhaps one more of them. A kiln of 3 to 3.5 m. interior diameter and about 15 m. in height may be regarded as a good-sized one for 1000 tons of beets. The width of a kiln can be reduced by an additional layer of firebrick.

We may distinguish three different zones in the interior of a kiln. The middle zone is the fire-zone, where the coke is burning and the dissociation of the carbonate of lime takes place. Below this there is another zone where the burned lime cools off, and above it there is a third zone where the hot gases transfer their heat to the material above the fire.

The fire-zone of a kiln should be kept as low as possible even if the lime is withdrawn a little hot. If the fire is too high, there is a large amount of burned lime underneath, carrying the whole load of the kiln contents, and due to this heavy weight, the burned lime naturally crumbles and pulverizes much more easily than the rock above. This pulverizing hinders the air circulation through the kiln and it is most important that this be kept as free as possible. At the same time the gases have a chance to cool, if the fire is low, and their heat is utilized by heating up the material above the fire.

The lime should be withdrawn from all around the kiln, or from each of the four doors, until it begins to show a slightly dark shade of red. This is about the only safe way to keep the fire-zone even all around the kiln.

This method of discharging the kilns has another advantage in that it shortens the zone of burned lime at the bottom of the kiln, reducing the danger of air-slacking by absorption of the moisture of the air which is drawn through the kiln by the gas pump. By adding more coke the fire-zone may be shortened; the air will then encounter more coke in a smaller space and the fire will be hotter but not so extensive.

The limestone for beet-sugar factory use should be as pure as possible, although the value of the material does not depend upon the chemical composition alone. There are kinds of limestone which, on account of their physical structure, are unfit to be burned; they crumble to a powder and this powder stops the circulation of gas through the kiln. The use of such material should be avoided. The most suitable limestone is one that burns without crumbling. The impurities of limestone, especially silicic acid, not only diminish the amount of carbonate of lime, but they combine, in burning with the burned lime and make it inactive and useless for our purpose. The relative commercial values of two limestones of which one is 100 per cent $CaCO_3$ and the other contains 3 per cent impurities are not as 100 : 97, but, according to Stohmann, as $100 : 100-3\times3$. Another point of importance is the manner in which the impurities are distributed in the rock. If the impurities are on the outside, as is usually the case with surface rock, they are much less objectionable than if they were evenly distributed throughout the rock.

In regard to the size of the pieces of limestone, it was stated above that a diameter of 5 or 6 inches had been found most favorable. At this size the circulation of the air and gases through the kiln is as good and free as it can be made. The pieces may be a little smaller than this, if they are kept uniform. It is very poor economy to allow splinters of rock to go into the charge together with pieces of the ordinary size. The small pieces, or splinters, fill up the space between the larger pieces, stop the air circulation and form a natural arch. Kilns charged in this way often burn to a solid mass and do not fall down when the kiln is discharged. They have to be pushed down with iron bars. In such cases of arching the percentage of CO_2 in the gas is apt to decrease considerably, sometimes falling below 20 per cent, as the gas pump takes air from all the leaks above the bridging.

In cases where a kiln burns unevenly, as it may after a long interruption or at the beginning of the campaign, much unburned or partially burned rock passes through the kiln. It is still more objectionable to return these pieces with unburned centers. If run through the kiln a second time they break to powder and stop the air circulation. At such times it is especially important to charge the kiln only with even pieces, so as to put it in order as quickly as possible. After a while, there will be no more pieces with unburned centers.

Another disadvantage of spalls is that they overburn, the lime combining with the impurities of the rock and becoming inactive. If the fire in the kiln is hot enough to burn the 5 or 6 inch pieces of rock, these small pieces will be overburned and their lime rendered inactive and worthless.

The amount of coke which a certain rock needs for thorough burning must be determined by experiment. Some kinds of rock burn more easily than others. It is safe to begin experimenting with about 10 per cent of coke. After a while, if the resulting lime remains unburned, the amount of coke must be gradually increased; if, on the other hand, the rock is overburned, less coke should be used. The coke should be broken up into 2 or 3 inch pieces and mixed thoroughly with each bucket of rock.

The fine dust of the coke should be kept out of the kiln, because it hinders the passage of gas. It is not burned away for a long time, because the gases in the upper part of the kiln contain no oxygen and cannot burn the coke.

Different kinds of coke are obtained from different sources, some having 3 or 4 per cent of ash and some as high as 20 per cent. The amount of coke required depends largely on the kind used. The limestone and the coke often contain sulphur, which does not do much harm as long as the kiln has a good, free gas circulation, in which case the sulphur is burned to SO_2, which helps in the saturation. The presence of H_2S in the gases is said to produce gray sugar.

The theoretical amount of CO_2 in the gas from pure limestone and 10 per cent of coke is about 37 per cent. An average of 33 per cent may be considered a good lime-kiln work. The kiln, gas pumps, etc., should be investigated when the gas falls below 28 per cent, although the carbonation may be carried on successfully with a 24 per cent gas. If the gas falls as low as 16 to 17 per cent the juice in the carbonation tanks foams to such an extent as to reduce the capacity of the house.

The gas from the kiln is sucked by the pump through a gas washer. It is generally dusty and carries tarry substances with it. The object of the gas washer is to remove these substances from the gas. The gas washers are generally cylinders with two perforated sheets, or, better still, two sets of iron bars, one 3 or 4 feet from the top, and one the same distance from the bottom. On these perforated sheets pieces of coke or limestone are spread, and water is sprinkled over them. The gas has to pass these layers and is washed in this way. At the bottom of the gas washers a sealed pipe leading to a well carries the wash water away. Many gas washers are in use which force the gas to pass through 3 or 4 feet of water. It should be borne in mind that in overcoming such a counterpressure the gas pump loses 10 per cent or more of its efficiency. Undesirable obstructions in the gas washer are easily detected by the use of water seals of glass tubing before and after the washing.

Sometimes the gas washers do not do the work expected of them, because of clogging of the water spray or for other reasons. As a consequence tarry substances get into the gas pumps, stopping the valves and sometimes causing serious trouble. For such emergencies there should be small ½ inch steam connections at the gas pump ahead of the suction valves, and between the suction and discharge valves, to blow them clean from time to time. Daily washing of the valves by drawing in kerosene helps the efficiency of the gas pumps.

Furthermore in making calculations for a gas pump it should be borne in mind that the pressure of the atmosphere for the Rocky Mountain States is considerably less than at sea level, and that, on this account the gases are about 20 per cent thinner than at sea level.

To gain an idea of the size of the gas pump required for a certain amount of lime we shall base our calculation on burning 100 long tons of limestone per day:

100 tons of limestone = 56 tons of lime and 44 tons of CO_2
10 per cent of coke of 85 per cent fixed carbon or 8.5 tons of fixed carbon = 31.2 tons of CO_2

Total, 75.2 tons of CO_2

$$75.2 \text{ tons} = 65{,}200{,}000 \text{ gr.}$$

At 620 mm. mercury pressure (which is the average for Colorado)

$$1 \text{ l. } CO_2 = 1.6 \text{ gr.}$$

or

$$75{,}200{,}000 \text{ gr.} = 47{,}000{,}000 \text{ l.}$$

The kiln gas may have 33.3 volume per cent of CO_2, then 141,000,000 l. of gas have to be pumped in twenty-four hours or 5,875,000 l. per hour, or 97,917 l. per minute.

If the gas pump is expected to make 60 revolutions per minute, one revolution of the pump = 1632 l. at 100 per cent efficiency of the pump. At 90 per cent efficiency of the pump the actual replacement of the pump should be 1814 l.

Most of the gas pumps in use are double-acting two-cylinder steam pumps. Therefore the size of the gas cylinders of such a pump should be 454 l. which is equivalent to a double-acting two-cylinder gas pump of 40 inches diameter and 24-inch stroke.

The temperature of the gas, after passing through the gas washer, is assumed to be the same as the temperature of the air in the kiln house.

Sometimes belt-driven gas pumps are used. They should be so constructed as to deliver the maximum gas requirement of the factory and should have a pipe and valve connection between discharge and suction line of the pump to regulate the amount of gas to be pumped from the kiln.

Some factories have gas pumps only large enough to carbonate the lime. They would not be large enough to produce the desired amount of lime. Such factories can help out the kilns by fans or blowers which suck the excess of gas from the kilns and discharge it to the air.

When a kiln is to be started, the lower cone should be filled with wood, after which about ten buckets of coke may be added, then perhaps 10 tons of rock together with 20 per cent of coke, after which the regular charge may be used. The kiln should be lighted with the chimney open and, without the help of the gas pump because the first gases are naturally very rich in tarry substances.

When a kiln is to be shut down it may be half emptied, then the gas pump must be closed, the top tightened with clay or sand and the fire smothered in this manner.

Wonderful control of the lime-kiln work can be obtained by the use of recording thermometers in the suction line of the gas pump, between the kiln and gas washer. Any irregularity in charging or discharging the kiln can be detected by a glance at these instruments.

CHAPTER XVI

STEFFEN'S SEPARATION

If a cold dilute sugar solution is treated with pulverized lime, the lime goes into solution, forming first a mono, then a bisaccharate solution with the sugar. In diluted molasses of about 7 per cent sugar, about 40 per cent of lime on sugar can be dissolved, being a little more than would correspond to a bisaccharate solution, which would be about 33 per cent. Such solution might be considered a bisaccharate solution in a lime-water solution. If the addition of pulverized lime is continued, while the solution is cold the precipitation of the cold calcium trisaccharate sets in. This precipitation of the sugar is generally continued until there remains in the waste water about 0.5 to 0.7 per cent of sugar. This is accomplished in the modern installations with 85 to 100 per cent of lime. The theoretical amount would be around 50 per cent or, considering the amount of lime staying in solution in the waste water, nearly 60 per cent, so that we have a mixture of trisaccharate and lime. The composition of the cold trisaccharate is not yet fully known. It is most decidedly different from the calcium trisaccharate which is formed when lime-sugar solutions are heated.

The precipitation of the cold calcium trisaccharate depends largely on the fineness of the lime, the concentration of the sugar solution, the temperature of the liquor, the circulation of the solution in the coolers, and the condition (presence or absence of foam) of the surface of the liquor in the coolers.

The burned lime from the kiln goes into crushers which are variously constructed. A common type is the jaw crusher, which crushes the lime into pieces about half an inch in diameter; rotary crushers of different types are also used. From these crushers the lime often passes through another machine to be broken into pieces about the size of a pea, and in this size the lime goes to the mills. Stone mills like those used for flour were originally employed for this purpose. These mills do not grind the lime very fine and it has to be bolted through sieves, which is very disagreeable work, the bolters breaking frequently and requiring continual repairing and changing. The lime dust attacks the mucous membranes of the workmen, making it very hard to keep men at these stations. The sieves used have 60 to 100 meshes to an inch. This is very coarse for the Steffen's reaction; but there is a practical limit to the size of the bolter station, and the capacity of a bolter would be very materially reduced by using finer sieves. The importance of having the lime in a finer condition is so great, however, that numerous attempts were made, long ago, to do away with the sieves and replace them with something better. A happy solution of this difficulty was found in an air separation of the lime. A strong current of air is directed against the falling lime and carries the finer particles away into settling chambers while the coarser particles fall back into the mill. For this purpose other types of mills were constructed and combined with the air separation of the lime. Lately the combination of the Raymond mill and the air separation has given very good results. The use of air separation and collection of the lime, in connection with the Raymond mill has brought about a change in the shape of the settling boxes. The air loaded with the lime enters a cylinder at a tangent; in this cylinder, the lime-carrying air is forced to change its direction, driving the lime particles with a centrifugal motion against the wall of the cylinder. The lime is thus separated and falls into the lower conical part of the separator, leaving the cone through doors which are opened by its weight. The lime-freed air leaves the separator at the center of the top and returns to the mill, where it takes up another load of fine lime. This mill consists of a cast-manganese-steel ring, against the inner wall of which heavy cast-iron rolls revolve, the ring and the rolls being above the point at which the air enters. The lime is thrown by plowlike arms between the ring and the rolls; and the air enters the mill through a series of tangential openings leading from the bottom upward against the lime. The air is thus loaded with lime powder and then enters a reversed cone above the mill. Another cone, suspended inside of this one, reverses the direction of the air current. The upper space between these two cones is occupied by little doors which open at a certain angle, so their tangents are at a certain distance from the center of the mill. By this arrangement the air is given a centrifugal motion sufficient to return the coarser part of the lime to the mill. The doors through which the lime returns to the mill, like those of the collector, are opened by the weight of the lime. An important improvement has been made in these mills in the form of an adjustable sleeve at the outlet of the inner cone. By lowering the cone the current of air is forced farther down and the coarser particles fall back again into the mill, the finer lime being carried out through the center of the top of the mill to the separator described above. As the same air is used over and over again, it becomes absolutely dry, and air-slacking of the lime cannot occur.

The angle of the vein doors in the mill has to be regulated so that a maximum fineness of the lime is obtained without unnecessarily reducing the capacity of the mill. The feed of the mill, which consists of a tourniquet, has to be regulated so that the lower passages, through which the air enters the mill, do not fill up with lime. The lime from these mills has a fineness which it was impossible for the old-fashioned mills to attain; and herein consists their superiority. The finer the lime is or, in other words, the more closely it approaches molecular size, the smoother and quicker is the reaction, and the less lime is required. Other mills of simpler construction would probably give equally good results if provided with air-separating devices.

From the collector the lime is carried up by means of an elevator to lime storage bins, which may be most conveniently placed over the coolers. From these bins the lime is fed to the coolers in different ways. The most accurate way, of course, is to weigh the lime entering each cooler. When this is done, the necessary amount of lime is determined by spindling and polarizing the waste water. The amount of lime necessary, according to this test, will serve as a guide for all the coolers. Spindling of the waste water may be repeated, however, for each cooler.

Many factories do not weigh the lime which is fed to the coolers, but run their lime-addition arrangements, tourniquets or screws, until the sugar in the waste water is sufficiently reduced. Such an arrangement is, of course, less reliable and depends too much on the care exercised by the operator. For this purpose a screw conveyor is far superior to a tourniquet, because the former arrangement adds the lime in a continuous stream and the amount of lime can easily be regulated by the speed of the screw; whereas the tourniquet adds a large amount of lime every time one of its chambers is emptied, and it is hard to avoid splashing and foaming of the liquor. Many factories have adopted a plan whereby the screw empties the lime, not into the cooler, but into a bolter, which distributes the lime evenly over the surface of the liquid in the cooler. As the purpose of the bolter is not to sift the lime, but only to distribute it, the mesh is very large, averaging twenty to forty meshes to the inch. A most satisfactory lime-adding arrangement is a scale under the lime reservoir or lime hopper. This scale empties the weighed lime into a screw conveyor which takes it, within a specified time, into a distributing bolter or through a chute directly into the cooler.

The molasses from the house generally has a density of about 80 to 85° Brix. For Steffen's separation the molasses has to be diluted. A certain quantity of molasses, the exact weight of which must be determined by test, is weighed in a molasses scale and emptied into a solution tank of the capacity of a cooler. This tank is provided with a stirring arrangement which should not run too fast in order not to beat the solution into foam; here the molasses is thinned with water and with wash water from the saccharate presses, to a density of about 10 to 12° Brix. with about 5 to 7 per cent of sugar. Repeated attempts have been made to keep the cooler solution at a higher density in order to avoid too much dilution, very thin waste water and sugar losses; but experience seems to prove that the best separation with the least lime addition takes place at about 7 per cent sugar. It is possible, however, to have a 5 or 6 per cent solution without using much more lime. The thinner solutions offer advantages in washing. It is essential that the water pipes and wash-water pipes connected with the solution tank enter this tank at the bottom, in order to avoid foaming of the solution, which might result if the water were poured in from the top.

From the solution tank the cooler-solution enters the cooler by a wide pipe at the bottom of the cooler. It is very important to avoid foam wherever it is likely to be formed. Foam floats on the surface of the liquor; the lime falls upon it, is moistened, and does not come in contact with the sugar molecules. This lime hydrates and is wasted, as far as this operation is concerned.

Different types of coolers are in common use. The latest forms, however, closely resemble the original Steffen cooler, as first constructed, the main difference being in the size, the present coolers being of larger dimensions. These coolers consist of a cylindrical body 7 feet 6 inches in diameter, with two tube sheets. Into the tube sheets cooling pipes about 7 feet long and 2½ inches in diameter are fastened. The center of the apparatus is a large circulating well, 36 inches in diameter, in which a propeller, revolving at about 180 revolutions per minute, forces the liquor down, which returns through the cooling pipes over the upper tube sheet, where the lime is dusted in, then down again through the center well. The circulation of the liquor in the cooler is of fundamental importance. It requires a very heavy movement to bring the powdered lime into contact with the sugar molecules, with which the lime forms the tricalcium saccharate. The slower the circulation is, the more chance there is for the lime to settle down at the bottom and to form hydrate. In the form of hydrate the lime dust does not form the trisaccharate.

Special care has to be taken to fill the cooler to the right depth. If the liquor is not deep enough it will be drawn into the center well in a deep funnel-shaped pool which will suck in a large amount of air. This air is atomized by the rapidly moving propeller and causes foam to cover the whole surface so that the lime cannot mingle with the liquor. If the depth of the liquor is too great, there is a quiet portion at the top, beneath which the heavy circulation goes on near the tube sheet. The right depth for the liquor has to be determined by experiment. Even when the depth is right, the liquor, drawn down the central well, coming up through the cooling pipes and flowing from the outside toward the middle, forms a little circular dead space over the center. By reducing the area of the central well by means of rings or cones at the top of it, the diameter of the dead space over the central well can be reduced considerably. The efficiency of the propeller working in the larger area of the well will not be decreased to any great extent by these attachments. Crosses of sheet iron inside of the well prevent the development of a circular motion, which tends to draw in air.

The cooling water generally enters the cooling chamber at the bottom, goes around the central well and leaves the cooler at the top, being compelled to take this route by a partition which extends from the outside of the cooling chamber to the central well. It seems to be essential to pump a large amount of cooling water through the cooler in order to have a swift flow over the cooling surface, and to insure the lowest possible temperature, which is one of the fundamental conditions for a low lime addition. The temperature seems to exert a greater influence when the lime used is rather coarse. There is a maximum temperature above which no calcium trisaccharate is formed, being about 25° C. or a little higher. In many countries, however, the temperature which is obtainable by the use of well, river, or ditch water at the time when the beet-sugar factories are running is far below the critical temperature; and it is only in the first weeks of the campaign that a high temperature might necessitate an increased lime addition. In this case, financial considerations must determine whether the costly installation of an ice-machine is justified or not.

In the modern Steffen plants the lime addition can be reduced to less than 100 per cent on the sugar in the molasses. Of this lime, about 10 per cent goes into the waste water, so that only 90 per cent on the sugar in the molasses goes to the carbonation. White sugar factories with Steffen's separation may have as an average 7 to 7.5 per cent of molasses with 3.5 to 3.75 per cent of sugar; this would mean a little over 3 per cent of lime on beets in the carbonation. White sugar factories need 2.5 to 3 per cent of lime for the purification of the juice, so that approximately the same amount of lime can be made to accomplish two things at the same time, i.e., it extracts the sugar from the molasses, and then it purifies the juice. For a factory which works only its own molasses there is little advantage in adding less lime in Steffen's separation than is needed in the beet house. In such a sugar factory, the omission of a costly ice plant may be very seriously considered. Many factories work without an ice plant, sending water from the main pump to the house and through the coolers. There the water acquires a small amount of heat which is desirable for some parts of the work, such as the diffusion battery. For other stations, such as the condensers, some additional water has to be pumped. In southern countries ice machines are a necessity.

The time necessary for the Steffen process seems to be very short, if all conditions are favorable, especially if the lime is very fine. The propeller drive in the modern coolers is generally located under the cooler through stuffing boxes, the packing of which requires special attention. Raw-hide leather is a good packing for these boxes, which are exposed to much grinding, if lime and grit get into them. This arrangement leaves the whole space above the liquor free for the lime-adding apparatus. Lime is usually added until the waste water contains about 0.5 per cent of sugar; then the cooler is emptied. The inlet and outlet valves should be as close to the cooler as possible, and are most effective if their seats are fastened to the cast-iron bottom of the cooler, thereby avoiding all corners and dead spaces. The outlet pipes should be short and wide to insure a rapid emptying of the cooler. If the coolers are connected directly with the saccharate pump, the latter should draw from the end of a common outlet manifold, so that no saccharate will be left standing in dead pipes. It is better to empty the coolers into special receiving tanks and here too, the inlet should be at the bottom of the tanks to avoid foam, because foaming of the contents is not desirable for the press work. From these tanks the saccharate press pump sends the contents of the cooler to the saccharate presses. A general remark here about saccharate pipe lines may shorten this treatise. The saccharate from the coolers is a mixture of heavy saccharate, CaO, and $Ca(OH)_2$ suspended in a very thin solution of waste water, so that it is very likely to settle if left standing. The CaO hydrates and heats and clogs up the pipes, and it is therefore of the utmost importance to keep this material moving. There should be a continuous circulation from the receiving tank through the pump to the presses. The safety return valve of the press pump should be at the end of the discharge line back to the receiving tank, or suction line of the press pump. All dead ends where the saccharate might settle, must be carefully avoided. The valves of the saccharate-receiving tanks should be close to the tanks and provision must be made for emptying the pipes between these valves and the pump, so that no pipes can become clogged. It is better to avoid elbows in these lines and to substitute cross pieces with plugs.

The saccharate press pump sends the contents of the cooler to the saccharate presses, which are of various types. The saccharate filters much more readily than the lime mud, and therefore the chambers of the saccharate presses are much thicker than those in the first filter presses, a thickness of 2 inches being generally adopted. As in the carbonation filter presses, the plates have both vertical and horizontal grooves at the top and bottom, or they have screens which are fastened on the plates. In the latter arrangement the central piece of the cast-iron plate can be separated from the plate and supported by the screens. The purpose of this is to avoid breaking the plates. It very often happens, especially with new or careless workmen, that the channels which carry the saccharate to the interior of the frames are choked up. In such a case, there remains a hollow frame between two full plates, and the pressure from the full chamber is generally strong enough to break the frames. If the plates have movable centers these breaks can be avoided, and only the screens will be damaged. It is very important to handle the presses with the utmost cleanliness, taking care that all the channels are open, that the filter cloth is not doubled, that no saccharate remains on the faced joints so that the presses are tight, etc. The more carefully the presses are handled, the lighter will be the work of running them, as they will not have to be reopened so often. Splashing presses reduce the purity of the saccharate to an undesirable extent. Copings around the openings to the saccharate hopper and sewer, or better, sump connections in the floor, etc., are to be recommended, so as to prevent, if possible, any of the waste water going back into the saccharate. The washing arrangement of the saccharate presses is often placed so that the cake can be washed from either side. Different solutions have been used for washing the saccharate. A thin solution of 0.25 to 0.5 per cent sugar saturated with lime has been used, as well as lime water; but pure cold water seems to give equally good results. The duration of the washing seems to be of importance. A slow washing with less water gives better results than a washing which is rushed. For filling the presses different factories use various degrees of pressure; but a pressure of 40 pounds seems likely to be generally adopted. In this case a 20-pound pressure of the wash water may be high enough to wash a 2-inch cake in thirty or forty minutes. It is hardly possible to give exact direction as to the different pressures and the time required for washing, as these things depend too much on the construction of the press, the thickness of the cake, etc. The filter cloth used in the saccharate presses is usually a coarse jute, two cloths being used on each plate. This cloth has to be wide enough to allow for shrinkage. When the cloth is new, it should extend 1 inch beyond the edge of the frames on either side. The length of the cloth should be ample, and an allowance of 4 inches on each end of the plate should be made for shrinkage in this direction. The filter cloth hardens in a short time and must then be changed. It is customary to use the old under cloth as a new upper cloth and renew the under cloth. A cloth lasts from one to two weeks. In some factories it is washed and used again; other factories use jute of a cheap quality for their presses and throw the used cloths away. Washing should be tried, however, before discarding the used cloth. Some of the above remarks apply to the hot carbonation filter presses and are repeated here to avoid referring to that chapter.

Wash water which contains high amounts of calcium bicarbonate should be treated with lime before being used in plate and frame presses for saccharate, because bicarbonates are precipitated in contact with caustic lime and settle on the filter cloth fiber, making it hard and brittle.

Other types of presses have been tried for the cold saccharate. Kelly presses have had a trial; but they are unfit for this station, because they use too much wash water; and the excess water and wash water together is more than can be taken care of in the cooler-solution tank. Water dilutes and decomposes saccharate and causes high sugar losses.

A very efficient filter, however—the Oliver vacuum filter—has recently come into use for cold saccharate filtration. Saccharate filters readily and therefore can be filtered with as little difference in pressure as there is between the atmosphere and a vacuum of about 20 inches.

This filter consists of a drum dressed with heavy cotton filter cloth. The drum is half submerged and rotates in a trough filled with the contents of the cooler. The outer part of the drum is connected by pipes with an ingenious valve disk which allows the application of different pressures to the different parts of the drum: high vacuum, for the part of the drum submerged in the trough; low vacuum, for that part of the drum which just emerges from the trough and which is washed by water spray; atmospheric pressure for a short distance on the drum circumference; and pressure to blow off the cake from the filter cloth, before it re-enters the trough with the cooler-contents.

These filters use very little wash water, coming as close as any filter to a mere displacement of waste water by wash water; and they yield as high a purity as any filter.

From the saccharate filters the cake falls into a hopper which carries it to saccharate-receiving tanks, where it is thinned to a milk with the sweet water from the hot filter presses. This milk is pumped to the carbonation and added to the diffusion juice. It is advisable to heat the saccharate in the saccharate-receiving tanks. From the higher temperature and the addition of sugar solution, there results a splitting up of the saccharate. However, the main advantage of this heating may be the following: The saccharate milk is very much lower in lime content than the milk of lime, and the large amount of this milk of saccharate which it would be necessary to add to the diffusion juice might bring down the temperature of the latter. The lower the temperature of the thin juice, the more lime goes into solution and the more hot trisaccharate is likely to be formed. This substance is much harder to carbonate than the lime hydrate and it tends to increase the sugar content of the lime mud in the carbonation presses.

The average true purity of the saccharate in a Steffen house may be 87; the average true purity of the Steffen house molasses may be 64. The losses in a Steffen house in waste water may be 8.5 per cent of the sugar in molasses. From these figures the theoretical extraction figures, as well as the practical results, show an extraction of about 66.5 per cent of the sugar in molasses, 25 per cent sugar in resulting molasses, and 8.5 per cent loss, or eight-twelfths of the molasses sugar in granulated, three-twelfths sugar in resulting molasses, and one-twelfth sugar lost. A Steffen separation working 7 per cent molasses with 3.5 per cent sugar has to rework about .9 per cent sugar from the molasses of its own production and about 2.5 per cent sugar in molasses resulting from beets, which is about the normal production of molasses sugar of a non-Steffen house.

The cold trisaccharate is a material which is easily filtered and should be easily washed; but there is a limit to the degree of purity which it can attain.

It appears that the purity depends to a great extent on the nature of the molasses and of the substances precipitated by lime from this molasses. Such non-sugar substances are partly decomposed again in the carbonation, go into solution and form molasses again, so that there will eventually be an accumulation of such substances which make the round of the factory and finally make it necessary to discard the molasses. The time for this elimination of molasses may be every four or six weeks at the beginning of the campaign and perhaps every two or three weeks at the end of the campaign. It may vary in different countries for molasses from different soil; and the only sure indication is the impossibility of obtaining the normal degree of purity under otherwise unchanged conditions. It appears that molasses from fermented beets carries more of these substances which are precipitated by lime and carried around. If a beet-sugar factory with Steffen's separation is so located as to be able to buy outside molasses from non-Steffen houses, it will pay to do so, and to discard a larger proportion of its own molasses, thus getting rid of impurities which would otherwise keep circulating through the house. The money expended for freight will be easily repaid by increased extraction.

The waste water, that is, the mother liquor of the cooler-contents in factories, without the hot saccharate process, runs to the sewer; and with it goes the first part of the wash water. The second part of the wash water is used to thin down the molasses in the solution tank.

It is quite possible, with well-burned lime of high purity, to precipitate the sugar from molasses in the cold saccharate process to an extent of 92 per cent with 100 per cent lime addition, or less. There are on record whole campaigns with 94 lime addition and 93 precipitation. When the price of sugar is high, it is advisable to carry the sugar extraction still farther, by means of the hot saccharate process.

If the waste water from the cold saccharate filters is heated to about 75° C., the hot trisaccharate is precipitated. This has been done advantageously in open cylindrical tanks provided with perforated steam coils and stirrers. It seems to be essential to give the hot saccharate time to become thoroughly crystalline in order to facilitate the filtering process. This can be done in closed heaters with steam injection, provided the heaters are big enough to allow the necessary time for the saccharate to become crystalline and filterable.

With the hot saccharate process it may be advisable not to carry the precipitation of the cold saccharate so far, but to send the cold waste water to the heaters with a sugar content of .8 to 1.00 or with 10 to 12 per cent of the original molasses sugar. This saves lime and carries the precipitation of the sugar in the hot process nearly, if not quite, as far, as if the sugar content of the cold wash water were around .5 per cent.

For the filtering, plate and frame presses have been in use. However, the hot alkaline wash water is very hard on filter cloth, and the use of plate and frame presses entails a great expense for cloth. Very successful experiments have recently been conducted with a combination of a Dorr thickener and small Oliver filters. This combination has been tried on a large scale and has passed the experimental stage.

The purities obtained in this filtration are as high as those of the cold saccharate cake. At a time like the present, when the price of sugar is high and that of molasses low, the hot saccharate process is one of the most profitable installations in a sugar factory.

The waste water and wash water from the hot filter station will have a sugar content of from 0 to .30. This waste water either runs to the sewer or is subjected to further treatment, to regain the potash salts contained in it. The waste water from the hot filtration will have from 0.3–0.7 per cent of lime, and, if treated for potash, has to be carbonated, filtered, and evaporated. The thick liquor resulting can be burned and will give some heat to be utilized in the evaporation. The resulting ashes are the salts taken from the soil, mostly K_2CO_3 potash, and should be returned to the soil. However, a large installation seems to be required, including carbonation tanks, hot mud presses, and evaporator station, and a kiln to burn the thick liquor. The dimensions of all these stations are somewhat large because the liquor is so thin.

A factory with a capacity of 1000 tons of beets with 7 per cent of molasses or 3.5 per cent of sugar in the molasses, will have 450 to 500 tons of cooler-solution waste water, or 400 to 450 tons of water to evaporate. This will mean a triple effect of 750 square m., or a quadruple effect of 1000 square m. heating surface and 20 to 25 additional tons of coal or 2 to 2.5 per cent on beets. These figures are given as a demonstration of the high initial cost and the high running expenses of the potash-recovering installation. Financial considerations must determine whether such a station will be profitable or whether artificial fertilizers can be obtained more cheaply from other sources.

During the War there could be no doubt as to the advantage of the installation like the above; but when normal commercial conditions are restored and cheap potash salts may be obtained from Europe, the imported product may be more economical. In addition to potash this waste water contains a great deal of nitrogen which is recovered and utilized in European factories. When both potash and nitrogen are utilized there may be possibilities of commercial returns. Some factories have constructed large reservoirs in which they store the Steffen waste water during the campaign. After the campaign they use their factory equipment for working their waste water to a thick liquor which they afterward burn.

Some factories may be so located that they are not allowed to send their Steffen waste water through the sewer into the river. Such factories, if they cannot irrigate their own factory land, may find it necessary to equip themselves with an installation like that described above.

CHAPTER XVII

OSMOSE PROCESS

The significance of this chapter is now almost exclusively a historical one. Very few osmose installations are now in operation; but at the present price of sugar and molasses it is still possible to derive profit from them.

The osmose process is based on the different rates of speed at which the various substances in the molasses are diffused into water through the walls of an artificial cell, made of sheets of parchment paper. Parchment paper, like the cellulose of the plant cell or animal membrane, is penetrable for certain substances and especially for crystalline ones. These substances are called crystalloids, and are distinguished from the colloids, which cannot penetrate such membranes. The crystalloids pass through these membranes at very different rates of speed. The salts of the molasses, especially the sodium and potassium salts, belong to the most rapidly diffusing materials. Sugar also diffuses rapidly, but not as rapidly as the salts mentioned.

If we have molasses on one side of a parchment sheet and water on the other, there will be a passage through the paper in both directions. The greater part of the salts, some sugar and some organic non-sugars will pass into the water, while water will pass through the paper in the opposite direction and will go into the molasses, thinning it down. In consequence of the faster diffusion of the salts of the molasses, we shall have, on the water side, a low-purity waste water and, on the other side, a solution which has lost, in proportion, more non-sugars than sugar, and the purity of which is consequently somewhat higher than the purity of the original molasses. It is, therefore, the object of the process to obtain a maximum elimination of non-sugars from the molasses, with a minimum of sugar losses, and also a maximum increase in the purity of the osmosed molasses over that of the original molasses.

It is possible to increase the purity of the molasses by 10 points or even more in the first osmose. This elimination of a part of the non-sugars enables the osmosed molasses to crystallize again after further concentration. The osmosed molasses is boiled to a fillmass which, after a few days, is again separated in centrifugal machines into sugar and molasses. The well-washed brown sugar is melted, filtered, and boiled into the first fillmass together with thick juice; the resulting molasses can be osmosed a second time. Here again considerable purification takes place, although not to the degree noted in the first osmose. The result is a second fillmass, from which sugar and molasses are again obtained; and the osmose can be applied a third time to the resulting molasses.

The size of the osmose station of a beet-sugar factory is generally such that the first osmose continues as long as the cutting of the beets during the campaign, whereas the second and third osmose operations are generally carried on for a few months after the campaign.

Herein may be seen an advantage and a disadvantage. The advantage consists in the possibility of keeping the different station foremen busy for several additional months, so that, if the work of cleaning, repairing the machinery, etc., is done after the campaign, many of the better men of the more important stations can be kept the year round. Another advantage consists in keeping the house warm during the cold months of January, February, and March, when there is most danger that the machinery will be damaged by freezing. The disadvantage of this after-campaign lies in the fact that a large amount of sugar is carried through to another year, with a loss of interest on the money represented by this sugar.

In describing the details of the process we shall confine ourselves to the description of the osmogenes built by the

Kilby Mfg. Co., Cleveland, Ohio. The same principles apply to all the different types of osmogenes, and machines of slightly different construction are easily understood by anyone familiar with one type.

The molasses is pumped to a reservoir above the osmose apparatus and is heated with closed steam coils to as high a temperature as possible; the same is done with the water. For this purpose the condensed water of the last bodies of the evaporators is generally used.

The osmogenes consist of iron heads between which wooden frames are tightened. Sheets of parchment paper are pressed between the frames, and the latter are provided with woven wire to keep the parchment paper in place and prevent it from being torn. The wooden frames have two channels at the bottom, one of which communicates with the interior of the cell formed by two parchment papers. The upper part of the frames is provided with three prolongations, two at the outside and one in the middle. These prolongations form two troughs on the top of the osmogene extending over the whole length of the machine. The frames are all alike and have open communications with the trough above on one side, and communications with the channel at the bottom on the other side. Frames are arranged alternately. When the wooden frames are arranged in this way there are, in the osmogene machine, two separate sets of cells, one set having an inlet at the bottom on one side of the machine and an outlet at the top on the other side, and another set of cells having inlets and outlets at the opposite sides. When one set of cells is charged with molasses and the other with water, cells full of molasses will alternate in the machine, with cells full of water so that, on one side of each parchment paper there is molasses and, on the other side, water.

Each set of cells has a pipe to show how high the liquor stands. This is of special importance in filling and emptying the machine, as the paper would be likely to break if one side were full and the other side empty.

The Kilby osmogenes generally have their inlets for both molasses and water at the bottom of the machine, and the outlets for both at the top, so that water and molasses run through the machine in the same direction. This is a mistake and results in a loss of one or two degrees of purity as compared with the same machine run with a counter current. These machines may be very easily adapted to a counter-current operation, by running the molasses in at the bottom and the thin osmosed molasses out at the top, while the clear water enters from the trough on top, goes downward and out at the bottom of the machine. The result of the counter-current method is not only a higher gain in purity, but also a higher concentration of the osmose waste water. The following are average figures for the work of several months. The data given were obtained in a factory which, during half of the campaign, ran molasses and water in the same direction, and during the other half, ran molasses from the bottom to the top and water in the opposite direction.

First Case. Molasses and water running in the same direction.

Molasses to be osmosed	Purity	61.67
Osmosed molasses	Purity	70.64
Increase in purity		8.97
Waste water	Brix.	1.17
	Purity	27.83

Second Case. Molasses and water running in a counter-current.

Molasses to be osmosed	Purity	59.79
Osmosed molasses	Purity	70.67
Increase in purity		10.88
Waste water	Brix.	1.624
	Purity	29.45

Practical experience has shown that the best results are obtained in osmosis if the density of the osmosed liquor is around 27° Brix. Therefore, the operator at the osmose station should be instructed to keep the density of the osmosed liquor between 25 and 30° Brix.

The osmose is most effective if applied to low purity syrups. This is self-evident, because the elimination of the rapidly diffused material, that is, the salts, will take place most quickly when the osmotic pressure of this material is highest and the molasses is least pure, i.e., when the molasses contains the greatest percentage of non-sugars and salts. Therefore it is a decided mistake to osmose high purity material; and the consolation derived from thinking that the osmose station will catch the sugar, if a faulty treatment of the second fillmass results in syrups of too high a purity, is mere self-deception. Processes based on osmosis of high green syrups simply show that their inventors did not understand the principle involved. The higher the purity of the material which is treated in the osmose, the smaller is the increase in purity and the higher are the losses in sugar. With a higher concentration of the sugar, the proportion of sugar and non-sugars passing through the parchment paper to the sewer is far more unfavorable for the yield of sugar, and much sugar which could have been recovered by crystallization is lost in the waste water.

We have already seen that by using a countercurrent in the osmogenes we gain not only a higher increase in purity, but also a higher density in the waste water. The amount of water required in the case for which we have given the figures would be eighteen times the weight of the molasses if molasses and water run in the same direction, and about 16.5 times this weight if they run in opposite directions. Recent experiments have shown that it is possible to run the osmogenes just as successfully, as regards the increase in purity, with about half the usual quantity of water. These experiments, of which the results are given below, have extended over a sufficiently long period of time to be convincing.

The arrangement used was a combination of two osmogenes. The molasses was run through each osmogene in the usual way, but the same water was run through both osmogenes. It was run in a countercurrent from the top to the bottom of the first osmogene and entered the second machine at the top, passing through this osmogene in a countercurrent and leaving the machine at the bottom. One would think that the purifying effect of the second machine would be slighter than that of the first one, but this was not the case. The figures given below are for molasses osmosed for the third time. This explains the small increase in purity. The following comparative tests were conducted side by side with the same molasses.

Usual method of running the Osmogenes.

Purity of molasses to be osmosed		59.74
Purity of osmosed molasses		68.39
Increase in purity		8.65
Waste water	Brix.	1.67
	Purity	45.64

Two machines combined. Molasses running through each machine independently, the same water running through both.

Purity of molasses to be osmosed		59.74
Purity of osmosed molasses, first machine		68.47
Increase in purity		8.73
Purity of osmosed molasses, second machine		68.90
Increase in purity		9.16
Waste water	Brix.	3.15
	Purity	43.32

In consequence of these tests all the osmogenes in the factory in question were given over to the combined method of operation. The saving in combining two machines consists in using less water (about eleven times the weight of the molasses), which means less heating and a saving of coal.

The sugar losses are not affected by the density of the waste water, but depend upon the purities of the osmosed molasses and of the waste water. In osmosis, the dry substances and the sugar of the molasses are split up and go partly into the osmosed liquor and partly into the waste water. The sum of both must be equal to the dry substance and the sugar in the original molasses. These relations are expressed in the following equation, where x is the dry substance of the waste water. The dry substance of the molasses to be osmosed is taken as 100. P' is the purity of the molasses to be osmosed, P^2 the purity of the osmosed molasses and P^3 the purity of the waste water.

$$100 \times P' = (100 - x)P^2 + xP^3 \quad \text{or} \quad x = 100\frac{P' - P^2}{P^3 - P^2}.$$

With the dry substance of the waste water and the purities of the different liquors all the other components are easily figured, but as a matter of fact the real practical yields of the osmose work are far below the theoretical calculation, and much sugar is destroyed by being kept so long at so high a temperature. There are also losses in emptying the osmogenes, losses by fermentation of the thin liquors, etc. A coefficient of sugar destruction should enter into the formulas to make the theoretical calculations agree with the practical results.

In filling a new machine, care must be taken to see that both sides of the parchment papers fill up evenly. Molasses and water have to run at about the same rate. Then, when the machine is full, the molasses is shut off and the water is allowed to run for a while, until the out-flowing molasses has a density of about 25 to 30° Brix. Then the molasses must be turned on again, to keep the osmosed liquor at this density. Another way of starting the osmogenes is to fill both sides of the machine with water, then let molasses run through one side and water through the other. By this procedure the molasses, when turned on, can run in a very full stream until the density of the osmosed liquor rises to 25° Brix. The flow of the molasses is then checked to keep the density of the osmosed liquor below 30° Brix. When the machine is running, the stream of molasses is about one-fifth the volume of the stream of water. The molasses outlet has to be kept about 40 to 50 mm. lower than the water outlet.

After the osmose apparatus has run for some time, the papers become coated, and the machine no longer gives a satisfactory increase in purity. The efficiency of a machine can be restored by reversing, that is, interchanging the water and molasses sides of the machine, running water where the molasses has been and vice versa.

Washing with soda-ash solution without opening the osmogene has been tried with good success. Sometimes a paper breaks in the machine. When this occurs, it is apparent at once in the density of the waste water. In order to avoid opening up the machine and spoiling all the other papers, it is customary to close up the outlet channels of this particular cell with a strip of wood, and go on working without wasting all the paper in the machine.

For dressing a fresh machine the parchment paper must be soaked in water.

The second and third osmose operations are entirely similar to the first, as far as the working of the machines is concerned. However, the oftener the molasses is osmosed, the more the quickly diffusing salts are exhausted. In the third osmose, an increase in purity of about 8 must be considered very good work. It probably does not pay to osmose a fourth time.

The osmosed liquor with a purity of about 70 and a density of 25 to 30° Brix. is boiled in a vacuum pan to a fillmass. For boiling this fillmass, low steam should be taken and the boiling process should be extended over as long a time as possible, so as to boil away the thin osmosed liquor as it comes from the osmogenes. If this thin liquor is left standing around for any length of time it is very liable to ferment. The alkalinity or acidity of the osmosed molasses should be watched, and if these liquors are acid lime must be added to produce a slight alkalinity. The osmose fillmasses are sometimes boiled blank, which can be done best with a spindle, because the string proof of this fillmass is very different from that of the second fillmass. This syrup begins to pull out to strings when it is still very thin.

It is better, however, to boil the osmose fillmasses to grain, like the second fillmasses. It will be necessary to start the pan in this case with a higher liquor, and for that purpose part of the osmose sugar should be melted and the grain started with this high purity liquor, after which the fillmass may be finished with the thin osmosed liquor. The boiling in this case is similar to the boiling of the after-product fillmass. Therefore, in regard to the boiling, crystallizer work, and spinning we refer to Chapter XIV in order to avoid unnecessary repetition. The main difference in the boiling is due to the thin consistency of the osmosed molasses. On this account care has to be taken not to take in too large a charge, in order to avoid melting the grain already formed.

The centrifugal syrup from this first osmose fillmass returns to the osmogenes and the osmosed liquor is boiled to a second osmose fillmass. The resulting centrifugal syrup is osmosed again; but with a third osmose the practical limit for profitable work seems to be reached.

The osmose waste water goes, as a rule, to the sewer. This water is one of the most objectionable waters, and if it can be used to irrigate some of the factory ground, this course should be pursued.

CHAPTER XVIII

BOILER-HOUSE

It is not our intention to describe in detail the different types of boilers, furnaces, grates, stokers, etc., but rather to confine ourselves to some general remarks concerning the special conditions found in beet sugar factories.

One of the distinguishing characteristics of a beet-sugar factory as compared with other industrial plants is the periodic character of its work. Beet-sugar factories operate only three to four months in the year and for that reason have to count more or less on employing new men every year. This affects most of the stations, but especially the boiler-house, because there the work is more in the nature of skilled labor than that of many of the other stations.

A good fireman is able to save considerable coal by intelligent firing. Many of the men applying for work as firemen in a beet-sugar boiler-house are far from understanding how to keep the fire even and thoroughly efficient. Black spots, indicating cinders, are often seen in the fire, and air in abundance passes through such places. Therefore the two shift foremen of the boiler-house should be kept the year round and employed at cleaning and repairing, if this is possible, when the plant is idle. This is also done in the case of the foremen of the diffusion, carbonation, lime kiln, etc. It is obvious that to such a factory, working only certain months in the year, all the different instruments which tend to show the quality of the work and help to improve it are of much more importance than they are to a factory where the same operators are working all the year round and constantly acquiring greater skill.in their work.

Where it is possible to weigh the coal going into the boiler-house this should be done. It might be possible, in a factory with very regular work, to regulate the wages of the firemen in accordance with the percentage of coal used on the beets sliced.

Water-meters for the boiler feed-water are used in some factories. If these water-meters are accurate enough they will furnish most valuable information. They have, of course, to be checked from time to time. Reliable water-meters will be of immense value in locating the reason for any excessive coal consumption that may occur either in the factory or in the boiler-house.

One of the most important features of the work in the boiler-house is the control of the flue gases. The draft in the chimney should be constantly watched. It is very probable that chimneys of the same dimensions give very different results at different altitudes, on account of the variation in the density of the air. At higher altitudes the height of the chimney should be increased or else forced draft should be applied to give the desired efficiency.

The temperature of the flue gases is another point worthy of attention. Too high a temperature of the flue gases indicates that their path through the boilers is too short, or that the dampers to the chimney are too wide open, so that the combustion gases are drawn too quickly past the places where they are intended to transmit their heat. It may also indicate that the boilers are badly scaled and do not absorb the heat—300° C. is considered a desirable temperature for the flue gases. This low temperature, however, must not be obtained by heating an unnecessary amount of air. If the grates of the boilers are not covered with coal and there are places where cinders predominate, an undue amount of cold air passes through. Defects in the brick work of the boilers also permit cold air to enter, reducing the temperature of the flue gases and their percentage of carbon dioxide. For these reasons a continuous control of the percentage of carbon dioxide in the flue gases is one of the most imperative needs of the boiler-house. In fact, the importance of this test is so great that many of the foreign factories pay their boiler-house men on this basis. An average of perhaps 10 per cent of CO_2 in the flue gases is taken as a standard and the firemen are paid a bonus for each additional tenth of a per cent. Thus a premium is put on good work. This plan of adjusting the wages of the firemen is probably more just than the practice of paying according to the percentage of coal on beets. For any one of a hundred reasons the factory may not be running at full capacity; but the machines will continue to run and steam will escape from the roof, without any fault on the part of the firemen.

In common coal furnaces, leaving out of consideration any installation of forced draft, producer-gas firing, or oil firing, the work is considered good if the CO_2 content of the flue gas is between 12 and 14 per cent. But if we examine the CO_2 percentages of our factories we must not be surprised to find figures as low as 4 to 6 per cent. The percentage of oxygen by volume in the air is about 20 per cent, and that would be the theoretical limit for the percentage of carbon dioxide in the flue gas, if the coal consisted only of carbon and contained no hydrogen, which is not the case. Part of the atmospheric oxygen burns to water with the hydrogen of the coal. It would be impossible to maintain a perfect combustion using all the available oxygen; therefore a certain surplus of air is necessary. Practical experience has shown that 12 to 14 per cent CO_2 in the flue gas is desirable as a safeguard against carbon monoxide, which would materially reduce the efficiency of the combustion. It is therefore logical to pay the firemen according to their results in regard to the percentage of CO_2.

In boiler plants where the gases have to pass through large spaces surrounded by brickwork, samples of the gases should be taken at two points, immediately after the combustion of the gases is completed, and also at the outlet of the flue, so as to make sure of the tightness of the brickwork.

For introducing the foregoing scheme, that is, paying the firemen according to the percentage of CO_2, various types of apparatus have been designed to give the engineer in charge the most complete control of these gases. These devices are based on the different specific gravitics of gases containing more or less carbonic acid. The records made by the apparatus are continually being photographed, thus making an uninterrupted control of the boiler-house possible.

Tests of this kind should be made continuously in all factories and the results should be followed up with a view to possible saving of fuel.

One of the most fortunate circumstances in a beet-sugar factory is an abundance of clean, non-scaling hot water for the boiler-house. This water comes from the vacuum-pan coils, from the condensation in the pipes, from the heaters, and from the evaporators. The condensed water of the first body of the evaporators is generally oily from the engine cylinders and should not be used. All the water condensed from the steam goes back to the boiler-house; and the only steam lost for boiler-feed purposes is that which is blown into syrups to heat them, or used for steaming the centrifugal machines, mixers, and vacuum pans. Such losses, however, are more than balanced by taking the condensed water from the steam chamber of the second, third, and fourth effect of the evaporators.

There is considerable water condensed under a high pressure in the steam lines and vacuum-pan coils. If this water leaves the traps and enters an open boiler-feed tank the higher temperature of the water will cause it to flash into steam, which escapes and is lost as boiler-feed water. Therefore this water, condensed under a high pressure, should be released first into a closed flash tank, connected with the exhaust steam line to catch all the evaporation in the exhaust steam line, and from this flash tank to the boiler-feed tank. Another point of importance is the size of the boiler-feed tank. In many factories the boiler-feed tank is too small, and if the steam consumption in the factory varies (it is never constant), there will be a rush of water overflowing the small feed tank. This water is of course, lost, and has to be replaced by cold water.

There is great danger, in a beet-sugar factory, that sugar will get into the boilers. There are different places where sugar may enter the boiler-feed water. In the evaporator station there is a possibility of boiling sugar over from one body into the next heating chamber. This, however, is the result of great carelessness and seldom occurs. Small traces of sugar may be carried over by entrainment, and this is especially likely to occur if leaky pipes permit the steam or vapor to penetrate from the heating chamber into the juice chamber of an evaporator body. In such cases the condensed water in the heating chamber of the next body will show traces of sugar.

During the regular run of an evaporator system there is always a higher pressure in the heating chambers than in the juice chambers of the different bodies, so that there is little probability that juice will go through the leaks against the higher pressure of the steam in the heating chamber. If, however, there are interruptions in the factory work and the evaporators are shut down, this difference in pressure will cease to exist. In such cases a large amount of juice may pass into the heating chamber of a leaky body and thence into the boiler-feed tank. It is therefore absolutely necessary to test the condensed water of the evaporators after each interruption of their regular work.

There are some heaters through which the juice is pumped with a higher pressure than that of the steam at the other side of the heating tubes. In this case the relative pressures are entirely different; and here a leak will result in a continuous stream of juice entering the boiler-feed water. All these heaters have to be tested regularly for sugar in the condensed water. If there is a leak in the vacuum-pan coils, a coil may fill up with juice before the steam is opened, and in that way some sugar may enter the boiler-feed water.

If from any of these sources a considerable amount of sugar has found its way into the boilers, the only thing to do is to blow the boilers off immediately and start again with fresh water. If the amount of sugar in the boilers is considerable, the sugar carbonizes on those places under which the fire is burning, prevents the water from getting to these places, heats the iron to red heat, and may cause dangerous explosions. In cases where large amounts of sugar have found their way into the boilers the water will take on a deep-brown color and will foam. The escaping steam has a very characteristic odor, which gives the first warning of the presence of sugar. Even small traces of sugar cause this particular odor. As said above, rather than run any risk, it is advisable if the water starts to foam and gets brown to blow off the boilers. If the sugar enters the boiler-feed water periodically, it may be possible to keep part of the boilers running and empty only those boilers which had just been fed when the sugar appeared. Small amounts of sugar in the boiler will result in a decomposition of the sugar and the formation of various acids which cause a quick corrosion of the iron. In a case of this kind it may not be necessary to shut down entirely, but only to blow off one boiler after the other, meanwhile keeping up the work of the house.

It is needless to say whenever sugar is present in the boilers, its source must be located and the leaks repaired to avoid a repetition of the occurrence.

Small traces of sugar in the boiler water cannot be avoided, and do not do much harm as long as the boiler water is kept alkaline. It is therefore advisable to add some soda ash to the boiler-feed water so as to maintain a slight alkalinity. A regular control of the water going to the boilers is absolutely necessary; and it is advisable to make a test once each shift on the alkalinity of the water of each boiler. Blowing off of small amounts of water from each boiler should be made a strict rule.

Another substance is found in the boiler-feed water of those beet-sugar factories which take the condensed water from the first body of the evaporators to the boiler-house—that is the oil which is carried by the exhaust steam from the steam cylinders of the engines, to the heating chamber of the first evaporator and from there to the boiler-feed tank. Oils or grease of vegetable or animal origin will split up, at the high temperature of the boilers, into free acids which corrode the iron. Such oils should not be used for greasing the engines; but mineral oils of high viscosity should be employed. These oils, getting into the boilers and combining with the loose mud which will be present if fresh water is used may form an incrustation on the heated iron, hence oil should be kept out of the boilers as much as possible. These oils can be easily kept out of the water by allowing the water-feed tank to overflow either continuously or occasionally. If the boiler-feed tank is of large dimensions the oil will have time to rise to the top of the water and, by a slight overflow from the tank, the greater part of the oil can be eliminated. Some factories use oil separators in the exhaust-steam line before it reaches the evaporators. If these devices are doing the work required, they offer another advantage in that they keep the oil out of the heating chamber of the first evaporator with a favorable result as regards the transmission of heat. There is enough condensed water for the boiler-house without drawing upon the first body of the evaporators.

The ammonia which is regularly found in the boiler-feed water is not an objectionable substance, but on the contrary, will help to reduce the slight acidity resulting from the decomposition of small traces of sugar. The ammonia is bad only where a large amount of cold hard water is used. Here the ammonia, together with carbonic acid, tends to precipitate the lime and form scales. If much scale has accumulated in the boiler plant from hard water before the campaign, it must be removed. This scale is generally calcium carbonate or calcium sulphate with more or less silicic acid. A scale of calcium sulphate may be boiled with soda ash; heating up and cooling down of the boiler sometimes breaks it off. Ordinarily, a mechanical cleaner is used for freeing the boilers from the scale. During the campaign there should not be any scale formed; and an increase of scale will indicate that cold water has been taken in.

The varying load on the boiler-house has already been discussed. The larger and fewer the vacuum pans in a factory are, the greater this fluctuation will be. It will be greatest, of course, where there is only one white and one brown fillmass pan. When such a pan is started, a large amount of steam is used in concentrating the thick juice; then, in the graining, almost no steam is used. For the boiling which follows a comparatively large quantity of steam is required, while very little is used in finishing the strike. If the sugar boiler does not use some judgment in starting a pan, but takes all the steam he can to concentrate his juice in the shortest time, he is very likely to reduce the pressure in the boiler-house and to slow down the engines and retard the whole house. A scheme to prevent such an abuse is to divide the boilers into two sets, one set for the engines alone, another for boiling purposes. If the steam in the latter set of boilers is reduced, the boiling will go on just as quickly as the steam is delivered; but the work of the main house will not be retarded. The two sets of boilers can be connected in such a way that surplus steam in the engine boilers may be discharged into the boilers used for boiling purposes.

The piping of such an installation is a little more extensive and will cause a little more condensation in the pipes; but the general operation of the factory will be more even, and therefore a separation of the steam may be recommended.

While not pertaining directly to the boiler-house, a few details of the hot-water system of a beet-sugar plant will be appropriate here.

The boiler-feed tank has an overflow to the hot-press wash-water tank or the hot-water supply-tank. This tank receives the condensed water of the first body of the evaporators; and all the condensed water pipes of the boiler-feed tank should have by-passes into the hot-press water tank, so that in case of sugar leaks, these waters may be kept out of the boiler-feed tank. The hot-press water tank furnishes the hot water for the presses and the rest of the house.

The hot wash-water tank has two overflows, one to the sewer and the other to the battery-supply tank. This latter tank has a connection, with float valve, from the condensed water tank of the pans and evaporators. Sometimes there is a double condenser for the evaporators, so that the first one is supplied with especially pure water. A separate condensed water-seal tank is connected with the battery-supply tank. Furthermore, there is a cold-water connection to the battery-supply tank to regulate the temperature of the water going to the battery.

CHAPTER XIX

MISCELLANEOUS

Centralization of Condensors and Vacuum Pumps

Allusion was made in Chapter XII, "First Fillmass and Remelt Sugars," to several plans for the arrangement of condensers and vacuum pumps, which will now be considered more in detail. In boiling a fillmass it is necessary to maintain different degrees of vacuum in the pan at different stages of the boiling process, avoiding a very high degree of vacuum, in order to increase the temperature of the fillmass.

It is evident that the most independent form for the condensing arrangement is attained when each pan has its own condenser and vacuum pump. In this case any desired vacuum can be obtained in the individual pan by checking the water valve of the condenser. This arrangement is, of course, a little more expensive to install; but its running expenses are no greater. A saving in the cost of the installation can be effected if the whole condensing system of a beet-sugar factory is centralized in one condenser and one vacuum pump. Such a centralization is possible, and the results obtained with such an installation are about as good as if the evaporators and pans had individual condensers and pumps; but the centralized installation requires close attention. The real objection to this type of installation is that the whole factory depends upon the one pump, whereas, in case of a breakdown in the decentralized, condensing installation, pipes can easily be connected with some other pump while the broken one is being repaired.

A third way of arranging the condensation is to combine several vacuum pans with one central vacuum pump. Each pan keeps its own condenser; but the pumps are replaced by one larger one. With this arrangement the vacuum has to be regulated with the water valve and the air valves to the pump. This, of course, is not such a simple and flexible arrangement as the one by which each pan has its own condenser and vacuum pump. The amount of money saved in the installation of such a centralized condensing apparatus may not be large enough to justify the sacrifice of independence and flexibility in the pans. The greatest disadvantage of connecting several pans is that when a new pan is opened in a careless way, it may influence the vacuum of the other pans.

In a centralized condenser installation, each pan has to have a big valve in its vapor line with a 4-inch bypass, and a 4-inch valve from one side of the big vapor valve to the other, in order to start the vacuum gradually when a pan has been shut down while being emptied.

Centralization of the Motive Power

The natural power for a beet-sugar factory is steam. No great saving would be effected if a factory were so located as to be able to use a natural water power. On the contrary this might be more expensive than steam. The cost of a turbine installation, electrical generators, etc., would be great, the boiler-house would have to be practically as large, perhaps 95 per cent of the size, of the boiler-house in a steam-driven beet-sugar factory, because all of the exhaust steam is used for boiling purposes in the evaporators. The steam condensed for the transformation of heat into motive power is very small. One calorie represents 424 mkg.* One H.P. is 75 mkg. per second, or 270,000 mkg. per hour. So one H.P. is equal to 637 calories per hour or, since 540 calories are freed by condensation of 1 kg. of steam, the amount of steam condensed by the transformation of heat into motive power is 1.18 kg. per hour and H.P. If a factory of 1000 tons uses 800 H.P., the amount of steam condensed for the transformation of heat into motive power is 22,656 kg. per twenty-four hours, or 6 per cent of the steam needed in the evaporators, which is 376,000 kg. Another 4 per cent may be used up in the excess of condensation caused by larger steam pipes, and in the cylinders, by radiation. So the total losses may be 10 per cent of the steam used in the evaporators. If this steam is half of the amount used in the entire factory, the actual saving in using the natural water power for driving the machinery of a beet-sugar factory would be 5 per cent of steam and consequently of coal.

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* Mkg. = meter kilogram.

In the old factories, every little corner had an engine and every pump its own direct-acting steam cylinder; and there was an abundance of exhaust steam not all of which could be used in the evaporators, because the latter were not used for heating purposes and therefore took only a limited amount of steam for concentrating the juice. The exhaust steam which was used for heating purposes was used only once; and the amount of steam which could not be used in the evaporators or for heating purposes went to the roof. Such a condition resulted of course in a high coal consumption. There were two ways of bettering this condition. One was to use the vapors from the evaporators, instead of live steam injectors, for heating the juices in the diffusion battery, and also to use this vapor for heating the thin and the thick juice and the juice after leaving the diffusion, as well as for boiling after-product fillmasses. In this way a much larger amount of steam was needed in the evaporators. The evaporation is done this way in a triple, quadruple, or quintuple effect, while the heaters may be considered as a double effect. At the same time the production of low-pressure steam (exhaust steam) was reduced by centralizing the motive power to one high-class engine driving almost the whole factory. It is a mistake, however, to carry centralization too far. The exhaust steam is reduced far below the amount necessary for the evaporators; and the safety of operation is greatly endangered.

A factory with a daily capacity of 1000 long tons of beets, heating the diffusion battery and the diffusion juice after leaving the battery with vapor from the second body of a quintuple evaporator, and heating the thin juice from the first body, uses in the heating chamber of this first body 376,000 kg. of steam in twenty-four hours. Such a factory, with Steffen's separation, may use 600 H.P. in its main engines. If these main engines are of first-class design, Corliss engines, for instance, they will not take more than 10 kg. of steam per H.P. per hour. That is 144,000 kg. per twenty-four hours. Such a factory may use 80 H.P. for the water pumps. If these water pumps are direct-acting duplex pumps (this is a very simple, cheap, and comparatively efficient type) they may take 18 kg. of steam per H.P. an hour, or 34,560 kg. per twenty-four hours. The vacuum pumps may take 80 H.P., with 12 kg. of steam per hour and H.P., i.e., 23,040 kg. of steam in twenty-four hours. The gas pumps may take 60 H.P., with 12 kg. of steam per H.P. an hour, that is 17,280 kg. per twenty-four hours. Together this means 218,880 kg. of steam against 376,000 kg. of steam for the evaporators, and shows that there is a large margin in the steam used in the evaporators, for the light engines, direct-acting steam pumps, air compressors, boiler-feed pumps, etc. A factory with an installation of this kind is decidedly on the safe side and should not blow exhaust steam to the roof.

In the case of the bigger machines, such as the water pumps, it may be a wise precaution to have two or three smaller pumps rather than one large pump of the same capacity, as the smaller units make the work safer.

For all cases where power is needed far away from the factory, for instance for pulp-drags to the silo in the warehouse, for the lime-kiln and in other remote places, electricity is one of our best servants in the beet-sugar industry. But electrical power, bought during the campaign from outside sources, is expensive if the evaporators take care of the exhaust steam produced in the generators installed at the factory.

WATER-CONSUMPTION OF A FACTORY

One of the most important questions for a beet-sugar factory is the water question, especially in the arid regions of the country where water is a scarce and expensive article. The water question, therefore, should be settled before a new factory is built. Scarcity of water is the surest means of putting a beet-sugar factory out of existence. The following calculations may give an idea of the quantity of water needed. Assume that the factory has a daily capacity of 1000 long tons of beets; it will use about 120 per cent of water on beets for diffusion juice, the same amount for pulp water, and about 60 per cent for cleaning out the cells, altogether 300 per cent in the diffusion. This may appear a conservative figure.

In case of a factory not heating the juices from the evaporators, the condenser of the quadruple evaporators will need 7840 cb.m. of water. If the juices are heated from the evaporators, the evaporator condensers will require 6384 cb.m. in twenty-four hours. A quintuple effect with heaters will need 3780 cb.m.

The first fillmass condenser may take approximately 5100 cb.m. and the second about 2600 cb.m. For cleaning the house, fluming the lime mud and for fresh water in the beet-washer another 100 per cent on beets will be required. Therefore, the water needed for a beet-sugar factory of 1000 long tons will be approximately:

In case of a factory not taking vapor from the evaporators of a quadruple effect:

3,000 cb.m. for diffusion;
7,840 cb.m. for evaporator condenser;
5,100 cb.m. for first pan condenser;
2,600 cb.m. for second fillmass;
1,000 cb.m. for miscellaneous purposes;

19,540 cb.m. in twenty-four hours, or 13 cb.m. per minute.

In case of a factory taking vapor for heaters from the quadruple evaporators:

3,000 cb.m. for diffusion;
6,384 cb.m. for evaporator condenser;
5,100 cb.m. for first pan condenser;
2,600 cb.m. for second fillmass condenser;
1,000 cb.m. for miscellaneous purposes;

18,084 cb.m. in twenty-four hours, or 12.5 cb.m. per minute.

In case of a quintuple effect with heaters from the evaporators:

3,000 cb.m. for diffusion;
3,780 cb.m. for evaporator condenser;
5,100 cb.m. for first pan condensor;
2,600 cb.m. for second pan condenser;
1,000 cb.m. for miscellaneous purposes;

15,480 cb.m. in twenty-four hours, or 10.8 cb.m. per minute.

The above figures are conservative, and leave some margin; but they show that a beet-sugar factory uses an enormous amount of water, and that, where water is scarce, it is worth while trying to save some of it.

Water Circulation to Save Water

When a factory has plenty of water, the bulk of it goes to the condensers and down to the condenser-seal tank, thence out to the beet flumes and, after fluming the beets, to the sewer.

The water in the condenser-seal tank is clean water, holding in solution a little ammonia, which is not objectionable for most factory uses, and it has a temperature of about 40° C. This high temperature is the only objectionable feature; and if this water is to be used again in the condensers it must be cooled by sending it over cooling towers or by pumping it through spray nozzles. The cooling, of course, takes place in consequence of an evaporation of water, and, by this evaporation and by losses in spraying, about 10 per cent of this water may be lost; but the bulk of it can be recovered and used over and over again in the condensers and in other parts of the house.

If this water is taken back to the main water intake, provision has to be made for the beet-flume water. For this purpose the flume water is pumped to settling ponds where the bulk of the dirt, beet roots, etc., is deposited and whence the water flows back again to the beet flumes. As this water is used over and over again, it is gradually enriched with organic material and would finally start to ferment, if no fresh water were added. Therefore, a part of the tail-tank water must run to the flume water settling pond or directly to the flumes where it continuously replaces a part of the flume water which goes through an overflow to the sewer.

The amount of the water used for the condensers of a beet-sugar factory is almost 75 per cent of the whole of the water used in the factory. Of this 75 per cent, 10 per cent may be lost by spraying and evaporating and 15 per cent of all the water may be used for renewing the flume water. So it appears that it is easy to save about 50 per cent of all the water used for a beet-sugar factory; and in cases of emergency this saving can be carried further. This water-circulation system appears to be a good safeguard against scarcity of water and can be recommended for all those factories which are liable to run short.

SEWER WATER PROBLEM

The sewer water of a beet-sugar factory is composed, first, of the water from the flumes and beet washers, which is the bulk of the sewer water; second, of the pulp water from the diffusion battery; third, of the flume water for the lime mud, if the lime mud is flumed out; fourth, of the osmose waste water and of the Steffen waste water.

When there is a big river near the factory, there is, as a rule, no difficulty in disposing of the sewer water; and a settling pond to deposit the sand; beet roots, etc., is in that case an adequate purifying installation for the sewer water. The self-purification of the flowing river water will do the rest. But where there is only a small stream of water, the sewer water problem may become a serious one; and in that case, it may be advisable to separate the sewer water and have two separate sewers, one for the cleaner and one for the more objectionable water. The bulk of the sewer water which comes from the flumes is not very objectionable. A settling pond for settling the sand and beet roots will be sufficient as a purifying installation. All the other waters cause more trouble. The osmose waste water is one of the worst waters in a beet-sugar factory, because it contains so much organic substance, sugar and salts, that it becomes foul and ill-smelling. On the other hand, the concentration of this water is not high enough to make it a paying proposition to concentrate it and burn it to recover the salts. There are, however, very few osmose factories left in this country. The waste waters of the Steffen process are better in that respect, because they have a density of about 6° Brix. against 2 to 3° Brix. in the case of the osmose waste water.

It might pay to concentrate the water from the Steffen process and burn it. Where there is no installation to do this, the best plan would be to use these waters for irrigating some factory grounds, if this can be done. The same applies to the pulp water. Nobody would object to the seepage water from such irrigation; and the salts of these waters would be valuable fertilizers. Where the lime mud from the filter presses is flumed out, diffusion pulp water might be used with advantage for this fluming, because the heavy lime mud will carry down much of the organic matter such as albumin, and will deposit pulp particles. The precipitation of organic substances might be made still more efficient by adding milk of lime, till this sewer water is decidedly alkaline; but the cost is usually prohibitive. However, a complete purification of the sewer waters of a beet-sugar factory has not yet been accomplished and may not be possible.

CHAPTER XX

USEFUL FORMULÆ AND TABLES FOR VARIOUS CALCULATIONS

The amount of diffusion juice drawn per 100 parts of cossettes at the battery is generally measured in measuring tanks but can be checked by the following formula:

S_1 = sugar in cossettes;
P_1 = sugar in pulp;
P_2 = sugar in pulp water;
S_2 = sugar in diffusion juice.

Then:

$$\frac{S_1-(P_1+P_2)}{S_2}\times 100 = \text{per cent of diffusion juice on beets.}$$

%

CaO IN MILK OF LIME, VARIOUS DENSITIES (15° C).

Milk of lime made with juice contains only about 85 per cent of the lime given in this table.

Degrees Brix.	Specific Gravity	Grams CaO per Liter.	Per Cent CaO by Weight.	Degrees Brix.	Specific Gravity.	Grams CaO per Liter.	Per Cent CaO by Weight.
25	1.107	135	12.2 ✓	36	1.160	203	17.5
26	1.111	141	12.6	37	1.165	209	17.9
27	1.116	147	13.2	38	1.170	215	18.4
28	1.120	153	13.7	39	1.175	221	18.8
29	1.125	159	14.1	40	1.180	228	19.3
30	1.130	165	14.6	41	1.185	235	19.8
31	1.135	171	15.1	42	1.190	242	20.3
32	1.140	177	15.5	43	1.195	248	20.8
33	1.145	183	16.0	44	1.200	255	21.3
34	1.150	189	16.4	45	1.205	262	21.7
35	1.155	195	16.9	46	1.210	269	22.2

The laboratory sheets generally give directly the weight per cent of CaO in milk of saccharate. The weight of the milk of saccharate multiplied by the per cent of CaO divided by 100 gives the weight of CaO added to each carbonation tank.

BRIX, BAUMÉ, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS

Table showing equivalent degrees Brix, degrees Baumé, specific gravity at 20/20° C., pounds per cubic foot, and pounds of dry substance per cubic foot, from values of the U. S. Bureau of Standards, supplemented by S. T. Osborn.

Explanation

The Baumé scale is based on a modulus of 145 and is derived from specific gravities at 20/20° C. (Bureau of Standards Baumé scale for sugar solutions). That is, if d = degrees Baumé and s = specific gravity at 20/20° C.

Then
$$d = 145 - \frac{145}{s}.$$

The values for specific gravity at 20/20° C. represent true specific gravity, i.e., the ratio of the weights *in vacuo* of equal volumes of the sugar solution and of water, based on the determinations of Plato.

The values for "pounds per cubic foot" represent weights at 20° C. in air against brass weights.

The values for "pounds of dry substance per cubic foot" are calculated by multiplying the "pounds per cubic foot" by the percentage of dry substance represented by the "degrees Brix." For impure sugar solutions these values are only approximate.

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
0.0	0.00	1.00000	62.25	0.00	1.5	0.84	1.00584	62.61	0.94
0.1	0.06	1.00039	62.27	0.06	1.6	0.90	1.00623	62.64	1.00
0.2	0.11	1.00078	62.30	0.12	1.7	0.95	1.00662	62.66	1.07
0.3	0.17	1.00117	62.32	0.19	1.8	1.01	1.00701	62.69	1.13
0.4	0.22	1.00155	62.35	0.25	1.9	1.07	1.00740	62.71	1.19
0.5	0.28	1.00194	62.37	0.31	2.0	1.12	1.00779	62.73	1.25
0.6	0.34	1.00233	62.40	0.37	2.1	1.18	1.00818	62.76	1.32
0.7	0.39	1.00272	62.42	0.44	2.2	1.23	1.00858	62.78	1.38
0.8	0.45	1.00311	62.44	0.50	2.3	1.29	1.00897	62.81	1.45
0.9	0.51	1.00350	62.47	0.56	2.4	1.34	1.00936	62.83	1.51
1.0	0.56	1.00389	62.49	0.62	2.5	1.40	1.00976	62.86	1.57
1.1	0.62	1.00428	62.52	0.69	2.6	1.46	1.01015	62.88	1.64
1.2	0.67	1.00467	62.54	0.75	2.7	1.51	1.01054	62.91	1.70
1.3	0.73	1.00506	62.56	0.81	2.8	1.57	1.01093	62.93	1.76
1.4	0.79	1.00545	62.59	0.88	2.9	1.62	1.01133	62.96	1.83

BRIX, BAUMÉ, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
3.0	1.68	1.01172	62.98	1.89	7.0	3.91	1.02770	63.97	4.47
3.1	1.74	1.01211	63.00	1.96	7.1	3.96	1.02810	64.00	4.54
3.2	1.79	1.01251	63.03	2.02	7.2	4.02	1.02851	64.03	4.60
3.3	1.85	1.01290	63.05	2.08	7.3	4.08	1.02892	64.05	4.67
3.4	1.90	1.01330	63.08	2.14	7.4	4.13	1.02932	64.08	4.74
3.5	1.96	1.01369	63.10	2.21	7.5	4.19	1.02973	64.10	4.80
3.6	2.02	1.01409	63.13	2.27	7.6	4.24	1.03013	64.13	4.87
3.7	2.07	1.01448	63.16	2.34	7.7	4.30	1.03054	64.15	4.94
3.8	2.13	1.01488	63.18	2.40	7.8	4.35	1.03095	64.18	5.01
3.9	2.18	1.01528	63.20	2.46	7.9	4.41	1.03136	64.20	5.07
4.0	2.24	1.01567	63.23	2.53	8.0	4.46	1.03176	64.23	5.14
4.1	2.29	1.01607	63.25	2.59	8.1	4.52	1.03217	64.25	5.20
4.2	2.35	1.01647	63.28	2.66	8.2	4.58	1.03258	64.28	5.27
4.3	2.40	1.01687	63.30	2.72	8.3	4.63	1.03299	64.30	5.33
4.4	2.46	1.01726	63.33	2.79	8.4	4.69	1.03340	64.33	5.40
4.5	2.52	1.01766	63.36	2.85	8.5	4.74	1.03381	64.36	5.47
4.6	2.57	1.01806	63.38	2.92	8.6	4.80	1.03422	64.38	5.54
4.7	2.63	1.01846	63.40	2.98	8.7	4.85	1.03463	64.40	5.60
4.8	2.68	1.01886	63.43	3.04	8.8	4.91	1.03504	64.43	5.67
4.9	2.74	1.01926	63.45	3.11	8.9	4.96	1.03545	64.46	5.74
5.0	2.79	1.01965	63.47	3.17	9.0	5.02	1.03586	64.48	5.80
5.1	2.85	1.02005	63.50	3.24	9.1	5.07	1.03627	64.50	5.87
5.2	2.91	1.02045	63.52	3.30	9.2	5.13	1.03668	64.53	5.94
5.3	2.96	1.02085	63.55	3.37	9.3	5.19	1.03709	64.56	6.00
5.4	3.02	1.02125	63.57	3.43	9.4	5.24	1.03750	64.58	6.07
5.5	3.07	1.02165	63.60	3.50	9.5	5.30	1.03792	64.61	6.14
5.6	3.13	1.02206	63.62	3.56	9.6	5.35	1.03833	64.63	6.20
5.7	3.18	1.02246	63.65	3.63	9.7	5.41	1.03874	64.66	6.27
5.8	3.24	1.02286	63.67	3.69	9.8	5.46	1.03915	64.69	6.34
5.9	3.30	1.02321	63.70	3.76	9.9	5.52	1.03957	64.72	6.41
6.0	3.35	1.02366	63.72	3.82	10.0	5.57	1.03998	64.74	6.47
6.1	3.41	1.02407	63.75	3.89	10.1	5.63	1.04039	64.77	6.54
6.2	3.46	1.02447	63.77	3.95	10.2	5.68	1.04081	64.79	6.61
6.3	3.52	1.02487	63.80	4.02	10.3	5.74	1.04122	64.82	6.68
6.4	3.57	1.02527	63.82	4.08	10.4	5.80	1.04164	64.84	6.74
6.5	3.63	1.02568	63.95	4.15	10.5	5.85	1.04205	64.87	6.81
6.6	3.69	1.02608	63.87	4.21	10.6	5.91	1.04247	64.90	6.88
6.7	3.74	1.02648	63.90	4.28	10.7	5.96	1.04288	64.92	6.95
6.8	3.80	1.02689	63.92	4.34	10.8	6.02	1.04330	64.95	7.01
6.9	3.85	1.02729	63.95	4.41	10.9	6.07	1.04371	64.97	7.08

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
11.0	6.13	1.04413	65.00	7.15	15.0	8.34	1.06104	66.05	9.91
11.1	6.18	1.04455	65.03	7.22	15.1	8.40	1.06147	66.08	9.98
11.2	6.24	1.04497	65.05	7.29	15.2	8.45	1.06190	66.11	10.05
11.3	6.30	1.04538	65.08	7.35	15.3	8.51	1.06233	66.13	10.12
11.4	6.35	1.04580	65.11	7.42	15.4	8.56	1.06276	66.16	10.19
11.5	6.41	1.04622	65.13	7.49	15.5	8.62	1.06319	66.19	10.26
11.6	6.46	1.04664	65.16	7.56	15.6	8.67	1.06362	66.21	10.33
11.7	6.52	1.04706	65.18	7.63	15.7	8.73	1.06405	66.24	10.40
11.8	6.57	1.04747	65.21	7.69	15.8	8.78	1.06448	66.27	10.47
11.9	6.63	1.04789	65.23	7.76	15.9	8.84	1.06491	66.29	10.54
12.0	6.68	1.04831	65.26	7.83	16.0	8.89	1.06534	66.32	10.61
12.1	6.74	1.04873	65.29	7.90	16.1	8.95	1.06577	66.35	10.68
12.2	6.79	1.04915	65.31	7.97	16.2	9.00	1.06621	66.38	10.75
12.3	6.85	1.04957	65.34	8.04	16.3	9.06	1.06664	66.40	10.82
12.4	6.90	1.04999	65.36	8.10	16.4	9.11	1.06707	66.43	10.89
12.5	6.96	1.05041	65.39	8.17	16.5	9.17	1.06751	66.46	10.97
12.6	7.02	1.05084	65.42	8.24	16.6	9.22	1.06794	66.48	11.04
12.7	7.07	1.05126	65.44	8.31	16.7	9.28	1.06837	66.51	11.11
12.8	7.13	1.05168	65.47	8.38	16.8	9.33	1.06881	66.54	11.18
12.9	7.18	1.05210	65.50	8.45	16.9	9.39	1.06924	66.56	11.25
13.0	7.24	1.05252	65.52	8.52	17.0	9.45	1.06968	66.59	11.32
13.1	7.29	1.05295	65.55	8.59	17.1	9.50	1.07011	66.62	11.39
13.2	7.35	1.05337	65.58	8.66	17.2	9.56	1.07055	66.65	11.46
13.3	7.40	1.05379	65.60	8.74	17.3	9.61	1.07098	66.67	11.53
13.4	7.46	1.05422	65.63	8.79	17.4	9.67	1.07142	66.70	11.61
13.5	7.51	1.05464	65.65	8.86	17.5	9.72	1.07186	66.73	11.68
13.6	7.57	1.05506	65.68	8.93	17.6	9.78	1.07229	66.75	11.74
13.7	7.62	1.05549	65.71	9.00	17.7	9.83	1.07273	66.78	11.82
13.8	7.68	1.05591	65.73	9.07	17.8	9.89	1.07317	66.81	11.89
13.9	7.73	1.05634	65.76	9.14	17.9	9.94	1.07361	66.84	11.96
14.0	7.79	1.05677	65.79	9.21	18.0	10.00	1.07404	66.86	12.03
14.1	7.84	1.05719	65.81	9.28	18.1	10.05	1.07448	66.89	12.11
14.2	7.90	1.05762	65.84	9.35	18.2	10.11	1.07492	66.92	12.18
14.3	7.96	1.05804	65.87	9.42	18.3	10.16	1.07536	66.95	12.25
14.4	8.01	1.05847	65.89	9.49	18.4	10.22	1.07580	66.97	12.32
14.5	8.07	1.05890	65.92	9.56	18.5	10.27	1.07624	67.00	12.40
14.6	8.12	1.05933	65.95	9.63	18.6	10.33	1.07668	67.03	12.47
14.7	8.18	1.05975	65.97	9.70	18.7	10.38	1.07712	67.06	12.54
14.8	8.23	1.06018	66.00	9.77	18.8	10.44	1.07756	67.08	12.61
14.9	8.29	1.06061	66.03	9.84	18.9	10.49	1.07800	67.11	12.68

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
19.0	10.55	1.07844	67.14	12.76	23.0	12.74	1.09636	68.26	15.70
19.1	10.60	1.07888	67.17	12.83	23.1	12.80	1.09681	68.28	15.77
19.2	10.66	1.07932	67.19	12.90	23.2	12.85	1.09727	68.31	15.84
19.3	10.71	1.07977	67.22	12.97	23.3	12.91	1.09772	68.34	15.92
19.4	10.77	1.08021	67.25	13.05	23.4	12.96	1.09818	68.37	16.00
19.5	10.82	1.08065	67.28	13.12	23.5	13.02	1.09863	68.40	16.07
19.6	10.88	1.08110	67.30	13.19	23.6	13.07	1.09909	68.43	16.14
19.7	10.93	1.08154	67.33	13.26	23.7	13.13	1.09954	68.46	16.22
19.8	10.99	1.08198	67.36	13.34	23.8	13.18	1.10000	68.49	16.30
19.9	11.04	1.08243	67.39	13.41	23.9	13.24	1.10046	68.52	16.38
20.0	11.10	1.08287	67.41	13.48	24.0	13.29	1.10092	68.54	16.45
20.1	11.15	1.08332	67.44	13.56	24.1	13.36	1.10137	68.57	16.52
20.2	11.21	1.08376	67.47	13.63	24.2	13.40	1.10183	68.60	16.60
20.3	11.26	1.08421	67.50	13.70	24.3	13.46	1.10229	68.63	16.67
20.4	11.32	1.08465	67.52	13.77	24.4	13.51	1.10275	68.66	16.75
20.5	11.37	1.08510	67.55	13.85	24.5	13.57	1.10321	68.69	16.83
20.6	11.43	1.08554	67.58	13.92	24.6	13.62	1.10367	68.72	16.90
20.7	11.48	1.08599	67.60	13.99	24.7	13.67	1.10413	68.75	16.98
20.8	11.54	1.08644	67.64	14.07	24.8	13.73	1.10459	68.78	16.05
20.9	11.59	1.08639	67.66	14.14	24.9	13.78	1.10505	68.80	17.13
21.0	11.65	1.08733	67.69	14.21	25.0	13.84	1.10551	68.82	17.21
21.1	11.70	1.08778	67.72	14.29	25.1	13.89	1.10597	68.85	17.28
21.2	11.76	1.08823	67.75	14.36	25.2	13.95	1.10643	68.88	17.36
21.3	11.81	1.08868	67.78	14.43	25.3	14.00	1.10689	68.91	17.43
21.4	11.87	1.08913	67.80	14.51	25.4	14.06	1.10736	68.94	17.51
21.5	11.92	1.08958	67.83	14.58	25.5	14.11	1.10782	68.97	17.59
21.6	11.98	1.09003	67.86	14.66	25.6	14.17	1.10828	69.00	17.66
21.7	12.03	1.09048	67.89	14.73	25.7	14.22	1.10874	69.03	17.74
21.8	12.09	1.09093	67.92	14.81	25.8	14.28	1.10921	69.06	17.82
21.9	12.14	1.09138	67.94	14.88	25.9	14.33	1.10967	69.08	17.89
22.0	12.20	1.09183	67.97	14.95	26.0	14.39	1.11014	69.11	17.97
22.1	12.25	1.09228	68.00	15.03	26.1	14.44	1.11060	69.14	18.05
22.2	12.31	1.09273	68.03	15.10	26.2	14.49	1.11106	69.17	18.12
22.3	12.36	1.09318	68.06	15.18	26.3	14.55	1.11153	69.20	18.20
22.4	12.42	1.09364	68.08	15.25	26.4	14.60	1.11200	69.23	18.28
22.5	12.47	1.09409	68.11	15.32	26.5	14.66	1.11246	69.26	18.35
22.6	12.52	1.09454	68.14	15.40	26.6	14.71	1.11293	69.29	18.43
22.7	12.58	1.09499	68.17	15.47	26.7	14.77	1.11339	69.32	18.51
22.8	12.63	1.09545	68.20	15.55	26.8	14.82	1.11386	69.34	18.58
22.9	12.69	1.09590	68.23	15.62	26.9	14.88	1.11433	69.37	18.66

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
27.0	14.93	1.11480	69.40	18.74	31.0	17.11	1.13378	70.59	21.88
27.1	14.99	1.11526	69.43	18.82	31.1	17.16	1.13426	70.62	21.96
27.2	15.04	1.11573	69.46	18.89	31.2	17.22	1.13474	70.65	22.04
27.3	15.09	1.11620	69.49	18.97	31.3	17.27	1.13522	70.68	22.12
27.4	15.15	1.11667	69.52	19.05	31.4	17.33	1.13570	70.71	22.20
27.5	15.20	1.11714	69.55	19.13	31.5	17.38	1.13619	70.74	22.28
27.6	15.26	1.11761	69.58	19.20	31.6	17.43	1.13667	70.77	22.36
27.7	15.31	1.11808	69.61	19.29	31.7	17.49	1.13715	70.80	22.44
27.8	15.37	1.11855	69.64	19.36	31.8	17.54	1.13764	70.83	22.52
27.9	15.42	1.11902	69.67	19.44	31.9	17.60	1.13812	70.86	22.60
28.0	15.48	1.11949	69.70	19.52	32.0	17.65	1.13861	70.89	22.68
28.1	15.53	1.11996	69.72	19.59	32.1	17.70	1.13909	70.92	22.77
28.2	15.59	1.12043	69.75	19.67	32.2	17.76	1.13958	70.95	22.85
28.3	15.64	1.12090	69.78	19.75	32.3	17.81	1.14006	70.98	22.93
28.4	15.69	1.12138	69.81	19.82	32.4	17.87	1.14055	71.01	23.01
28.5	15.75	1.12185	69.84	19.90	32.5	17.92	1.14103	71.04	23.09
28.6	15.80	1.12232	69.87	19.98	32.6	17.98	1.14152	71.07	23.17
28.7	15.86	1.12280	69.90	20.06	32.7	18.03	1.14201	71.10	23.25
28.8	15.91	1.12327	69.93	20.14	32.8	18.08	1.14250	71.13	23.33
28.9	15.97	1.12374	69.96	20.22	32.9	18.14	1.14298	71.16	23.41
29.0	16.02	1.12422	69.99	20.30	33.0	18.19	1.14347	71.19	23.49
29.1	16.08	1.12469	70.02	20.38	33.1	18.25	1.14396	71.22	23.57
29.2	16.13	1.12517	70.05	20.45	33.2	18.30	1.14445	71.25	23.66
29.3	16.18	1.12564	70.08	20.53	33.3	18.36	1.14494	71.28	23.74
29.4	16.24	1.12612	70.11	20.61	33.4	18.41	1.14543	71.31	23.82
29.5	16.29	1.12659	70.14	20.69	33.5	18.46	1.14592	71.34	23.90
29.6	16.35	1.12707	70.17	20.77	33.6	18.52	1.14641	71.37	23.98
29.7	16.40	1.12755	70.20	20.85	33.7	18.57	1.14690	71.40	24.06
29.8	16.46	1.12802	70.23	20.93	33.8	18.63	1.14739	71.43	24.14
29.9	16.51	1.12850	70.26	21.01	33.9	18.68	1.14788	71.46	24.22
30.0	16.57	1.12898	70.29	21.08	34.0	18.73	1.14837	71.50	24.31
30.1	16.62	1.12946	70.32	21.17	34.1	18.79	1.14886	71.53	24.39
30.2	16.67	1.12993	70.35	21.25	34.2	18.84	1.14936	71.56	24.57
30.3	16.73	1.13041	70.38	21.32	34.3	18.90	1.14985	71.59	24.56
30.4	16.78	1.13089	70.41	21.40	34.4	18.95	1.15034	71.62	24.64
30.5	16.84	1.13137	70.44	21.48	34.5	19.00	1.15084	71.65	24.72
30.6	16.89	1.13185	70.47	21.56	34.6	19.06	1.15133	71.68	24.80
30.7	16.95	1.13233	70.50	21.64	34.7	19.11	1.15183	71.71	24.88
30.8	17.00	1.13281	70.53	21.72	34.8	19.17	1.15232	71.74	24.97
30.9	17.05	1.13329	70.56	21.80.	34.9	19.22	1.15282	71.77	25.05

BRIX, BAUMÉ, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
35.0	19.28	1.15331	71.08	25.13	39.0	21.43	1.17341	73.06	28.49
35.1	19.33	1.15381	71.83	25.21	39.1	21.48	1.17392	73.09	28.58
35.2	19.38	1.15430	71.86	25.29	39.2	21.54	1.17443	73.12	28.66
35.3	19.44	1.15480	71.89	25.38	39.3	21.59	1.17494	73.15	28.75
35.4	19.49	1.15530	71.93	25.46	39.4	21.64	1.17545	73.18	28.83
35.5	19.55	1.15579	71.96	25.55	39.5	21.70	1.17596	73.21	28.92
35.6	19.60	1.15629	71.99	25.63	39.6	21.75	1.17648	73.25	29.01
35.7	19.65	1.15679	72.02	25.71	39.7	21.80	1.17699	73.28	29.09
35.8	19.71	1.15729	72.05	25.79	39.8	21.86	1.17750	73.31	29.18
35.9	19.76	1.15778	72.08	25.88	39.9	21.91	1.17802	73.34	29.26
36.0	19.81	1.15828	72.11	25.96	40.0	21.97	1.17853	73.37	29.35
36.1	19.87	1.15878	72.14	26.04	40.1	22.02	1.17904	73.41	29.44
36.2	19.92	1.15928	72.18	26.13	40.2	22.07	1.17956	73.44	29.52
36.3	19.98	1.15978	72.21	26.21	40.3	22.13	1.18007	73.47	29.61
36.4	20.03	1.16028	72.24	26.30	40.4	22.18	1.18058	73.50	29.69
36.5	20.08	1.16078	72.27	26.38	40.5	22.23	1.18110	73.53	29.78
36.6	20.14	1.16128	72.30	26.46	40.6	22.29	1.18162	73.57	29.87
36.7	20.19	1.16178	72.33	26.55	40.7	22.34	1.18213	73.60	29.96
36.8	20.25	1.16228	72.36	26.63	40.8	22.39	1.18265	73.63	30.04
36.9	20.30	1.16279	72.39	26.71	40.9	22.45	1.18316	73.66	30.13
37.0	20.35	1.16329	72.42	26.80	41.0	22.50	1.18368	73.70	30.22
37.1	20.41	1.16379	72.46	26.88	41.1	22.55	1.18420	73.73	30.30
37.2	20.46	1.16430	72.49	26.97	41.2	22.61	1.18472	73.76	30.39
37.3	20.52	1.16480	72.52	27.05	41.3	22.66	1.18524	73.79	30.48
37.4	20.57	1.16530	72.55	27.13	41.4	22.72	1.18575	73.82	30.56
37.5	20.62	1.16581	72.58	27.22	41.5	22.77	1.18627	73.86	30.65
37.6	20.68	1.16631	72.61	27.30	41.6	22.82	1.18679	73.89	30.74
37.7	20.73	1.16682	72.65	27.39	41.7	22.88	1.18731	73.92	30.82
37.8	20.78	1.16732	72.68	27.47	41.8	22.93	1.18763	73.95	30.91
37.9	20.84	1.16783	72.71	27.56	41.9	22.98	1.18835	73.99	31.00
38.0	20.89	1.16833	72.74	27.64	42.0	23.04	1.18887	74.02	31.09
38.1	20.94	1.16884	72.77	27.73	42.1	23.09	1.18939	74.05	31.18
38.2	21.00	1.16934	72.80	27.81	42.2	23.14	1.18992	74.08	31.26
38.3	21.05	1.16985	72.83	27.89	42.3	23.20	1.19044	74.12	31.35
38.4	21.11	1.17036	72.87	27.98	42.4	23.25	1.19096	74.15	31.44
38.5	21.16	1.17087	72.90	28.07	42.5	23.30	1.19148	74.18	31.53
38.6	21 21	1.17138	72.93	28.15	42.6	23.36	1.19201	74.21	31.61
38.7	21.27	1.17188	72.96	28.24	42.7	23.41	1.19253	74.24	31.70
38.8	21.32	1.17239	72.99	28.32	42.8	23.46	1.19305	74.28	31.79
38.9	21.38	1.17290	73.02	28.40	42.9	23.52	1.19358	74.31	31.88

BRIX, BAUMÉ, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
43.0	23.57	1.19410	74.34	31.97	47.0	25.70	1.21538	75.67	35.56
43.1	23.62	1.19463	74.38	32.06	47.1	25.75	1.21592	75.70	35.65
43.2	23.68	1.19515	74.41	32.15	47.2	25.80	1.21646	75.73	35.74
43.3	23.73	1.19568	74.44	32.23	47.3	25.86	1.21700	75.77	35.84
43.4	23.78	1.19620	74.48	32.32	47.4	25.91	1.21755	75.80	35.93
43.5	23.84	1.19673	74.51	32.41	47.5	25.96	1.21809	75.84	36.02
43.6	23.89	1.19726	74.54	32.50	47.6	26.01	1.21863	75.87	36.11
43.7	23.94	1.19773	74.57	32.59	47.7	26.07	1.21917	75.91	36.21
43.8	24.00	1.19831	74.61	32.68	47.8	26.12	1.21971	75.94	36.30
43.9	24.05	1.19884	74.64	32.77	47.9	26.17	1.22026	75.97	36.39
44.0	24.10	1.19936	74.67	32.86	48.0	26.23	1.22080	76.01	36.48
44.1	24.16	1.19989	74.71	32.95	48.1	26.28	1.22134	76.04	36.58
44.2	24.21	1.20042	74.74	33.04	48.2	26.33	1.22189	76.08	36.67
44.3	24.26	1.20095	74.77	33.12	48.3	26.38	1.22243	76.11	36.76
44.4	24.32	1.20148	74.80	33.21	48.4	26.44	1.22298	76.14	36.85
44.5	24.37	1.20201	74.84	33.30	48.5	26.49	1.22352	76.18	36.95
44.6	24.42	1.20254	74.87	33.39	48.6	26.54	1.22406	76.21	37.04
44.7	24.48	1.20307	74.90	33.48	48.7	26.59	1.22461	76.24	37.13
44.8	24.53	1.20360	74.94	33.57	48.8	26.65	1.22516	76.28	37.22
44.9	24.58	1.20414	74.97	33.66	48.9	26.70	1.22570	76.31	37.32
45.0	24.63	1.20467	75.00	33.75	49.0	26.75	1.22625	76.35	37.41
45.1	24.69	1.20520	75.04	33.84	49.1	26.81	1.22680	76.38	37.50
45.2	24.74	1.20573	75.07	33.93	49.2	26.86	1.22735	76.41	37.59
45.3	24.79	1.20627	75.11	34.02	49.3	26.91	1.22789	76.45	37.68
45.4	24.85	1.20680	75.14	34.11	49.4	26.96	1.22844	76.48	37.78
45.5	24.90	1.20733	75.17	34 20	49.5	27.02	1.22899	76.52	37.87
45.6	24.95	1.20787	75.20	34.29	49.6	27.07	1.22954	76.55	37.97
45.7	25.01	1.20840	75.24	34.38	49.7	27.12	1.23009	76.59	38.07
45.8	25.06	1.20894	75.27	34.47	49.8	27.18	1.23064	76.62	38.16
45.9	25.11	1.20947	75.30	34.56	49.9	27.23	1.23119	76.66	38.25
46.0	25.17	1.21001	75.33	34.65	50.0	27.28	1.23174	76.69	38.35
46.1	25.22	1.21054	75.37	34.74	50.1	27.33	1.23229	76.72	38.43
46.2	25.27	1.21108	75.40	34.83	50.2	27.39	1.23284	76.76	38.53
46.3	25.32	1.21162	75.43	34.92	50.3	27.44	1.23340	76.79	38.63
46.4	25.38	1.21215	75.47	35.02	50.4	27.49	1.23395	76.83	38.72
46.5	25.43	1.21269	75.50	35.11	50.5	27.54	1.23450	76.86	38.81
46.6	25.48	1.21323	75.53	35.20	50.6	27.60	1.23506	76.90	38.91
46.7	25.54	1.21377	75.57	35.29	50.7	27.65	1.23561	76.93	39.00
46.8	25.59	1.21431	75.60	35.38	50.8	27.70	1.23616	76.97	39.09
46.9	25.64	1.21484	75.63	35.47	50.9	27.75	1.23672	77.00	39.19

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
51.0	27.81	1.23727	77.03	39.29	55.0	29.90	1.25976	78.44	43.14
51.1	27.86	1.23782	77.07	39.38	55.1	29.95	1.26033	78.47	43.24
51.2	27.91	1.23838	77.10	39.47	55.2	30.00	1.26090	78.51	43.34
51.3	27.96	1.23894	77.13	39.57	55.3	30.06	1.26147	78.54	43.43
51.4	28.02	1.23949	77.17	39.67	55.4	30.11	1.26204	78.58	43.53
51.5	28.07	1.24005	77.21	39.76	55.5	30.16	1.26261	78.61	43.63
51.6	28.12	1.24060	77.24	39.86	55.6	30.21	1.26319	78.65	43.73
51.7	28.17	1.24116	77.28	39.95	55.7	30.26	1.26376	78.69	43.83
51.8	28.23	1.24172	77.31	40.05	55.8	30.32	1.26433	78.72	43.98
51.9	28.28	1.24228	77.35	40.14	55.9	30.37	1.26490	78.76	44.03
52.0	28.33	1.24284	77.38	40.24	56.0	30.42	1.26548	78.79	44.12
52.1	28.38	1.24339	77.42	40.34	56.1	30.47	1.26605	78.83	44.22
52.2	28.44	1.24395	77.45	40.43	56.2	30.52	1.26663	78.86	44.32
52.3	28.49	1.24451	77.49	40.53	56.3	30.57	1.26720	78.90	44.42
52.4	28.54	1.24507	77.52	40.62	56.4	30.63	1.26778	78.93	44.52
52.5	28.59	1.24563	77.56	40.72	56.5	30.68	1.26835	78.97	44.62
52.6	28.65	1.24619	77.59	40.81	56.6	30.73	1.26893	79.01	44.72
52.7	28.70	1.24675	77.63	40.91	56.7	30.78	1.26950	79.04	44.82
52.8	28.75	1.24731	77.66	41.00	56.8	30.83	1.27008	79.08	44.92
52.9	28.80	1.24788	77.70	41.10	56.9	30.89	1.27066	79.11	45.01
53.0	28.86	1.24844	77.73	41.20	57.0	30.94	1.27123	79.15	45.11
53.1	28.91	1.24900	77.77	41.29	57.1	30.99	1.27181	79.19	45.21
53.2	28.96	1.24956	77.80	41.39	57.2	31.04	1.27239	79.22	45.31
53.3	29.01	1.25013	77.84	41.49	57.3	31.09	1.27297	79.26	45.42
53.4	29.06	1.25069	77.87	41.58	57.4	31.15	1.27355	79.29	45.51
53.5	29.12	1.25126	77.91	41.68	57.5	31.20	1.27413	79.33	45.61
53.6	29.17	1.25182	77.94	41.78	57.6	31.25	1.27471	79.37	45.71
53.7	29.22	1.25238	77.98	41.87	57.7	31.30	1.27529	79.40	45.81
53.8	29.27	1.25295	78.01	41.97	57.8	31.35	1.27587	79.44	45.92
53.9	29.32	1.25351	78.05	42.07	57.9	31.40	1.27645	79.48	46.02
54.0	29.38	1.25408	78.08	42.16	58.0	31.46	1.27703	79.51	46.12
54.1	29.43	1.25475	78.12	42.26	58.1	31.51	1.27761	79.55	46.22
54.2	29.48	1.25521	78.15	42.36	58.2	31.56	1.27819	79.58	46.32
54.3	29.53	1.25578	78.19	42.46	58.3	31.61	1.27878	79.62	46.42
54.4	29.59	1.25635	78.22	42.55	58.4	31.66	1.27936	79.66	46.52
54.5	29.64	1.25692	78.26	42.65	58.5	31.71	1.27994	79.69	46.62
54.6	29.69	1.25748	78.29	42.75	58.6	31.76	1.28052	79.73	46.72
54.7	29.74	1.25805	78.33	42.85	58.7	31.82	1.28111	79.77	46.82
54.8	29.80	1.25862	78.36	42.94	58.8	31.87	1.28169	79.80	46.92
54.9	29.85	1.25919	78.40	43.04	58.9	31.92	1.28228	79.84	47.03

BRIX, BAUMÉ, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
59.0	31.97	1.28286	79.88	47.13	63.0	34.02	1.30657	81.35	51.25
59.1	32.02	1.28345	79.91	47.23	63.1	34.07	1.30718	81.39	51.36
59.2	32.07	1.28404	79.95	47.33	63.2	34.12	1.30778	81.43	51.46
59.3	32.13	1.28462	79.99	47.43	63.3	34.18	1.30838	81.47	51.57
59.4	32.18	1.28520	80.02	47.53	63.4	34.23	1.30898	81.50	51.67
59.5	32.23	1.28579	80.06	47.64	63.5	34.28	1.30958	81.54	51.78
59.6	32.28	1.28638	80.10	47.74	63.6	34.33	1.31019	81.58	51.88
59.7	32.33	1.28697	80.13	47.84	63.7	34.38	1.31079	81.62	51.99
59.8	32.38	1.28755	80.17	47.94	63.8	34.43	1.31139	81.65	52.09
59.9	32.43	1.28814	80.20	48.04	63.9	34.48	1.31200	81.69	52.20
60.0	32.49	1.28873	80.24	48.14	64.0	34.53	1.31260	81.73	52.31
60.1	32.54	1.28932	80.28	48.25	64.1	34.58	1.31320	81.77	52.41
60.2	32.59	1.28991	80.31	48.35	64.2	34.63	1.31381	81.80	52.52
60.3	32.64	1.29050	80.35	48.45	64.3	34.68	1.31441	81.84	52.62
60.4	32.69	1.29109	80.39	48.56	64.4	34.74	1.31502	81.88	52.73
60.5	32.74	1.29168	80.43	48.66	64.5	34.79	1.31563	81.92	52.84
60.6	32.79	1.29227	80.46	48.76	64.6	34.84	1.31623	81.96	52.94
60.7	32.85	1.29286	80.50	48.86	64.7	34.89	1.31684	81.99	53.05
60.8	32.90	1.29346	80.54	48.96	64.8	34.94	1.31745	82.03	53.16
60.9	32.95	1.29405	80.57	49.07	64.9	34.99	1.31806	82.07	53.26
61.0	33.00	1.29464	80.61	49.17	65.0	35.04	1.31866	82.11	53.37
61.1	33.05	1.29523	80.65	49.28	65.1	35.09	1.31927	82.14	53.47
61.2	33.10	1.29583	80.68	49.38	65.2	35.14	1.31988	82.18	53.58
61.3	33.15	1.29642	80.72	49.48	65.3	35.19	1.32049	82.22	53.69
61.4	33.20	1.29701	80.76	49.59	65.4	35.24	1.32110	82.26	53.80
61.5	33.26	1.29761	80.79	49.69	65.5	35.29	1.32171	82.30	53.91
61.6	33.31	1.29820	80.83	49.79	65.6	35.34	1.32232	82.33	54.01
61.7	33.36	1.29880	80.87	49.90	65.7	35.39	1.32293	82.37	54.12
61.8	33.41	1.29940	80.91	50.00	65.8	35.45	1.32354	82.41	54.23
61.9	33.46	1.29999	80.94	50.10	65.9	35.50	1.32415	82.45	54.33
62.0	33.51	1.30059	80.98	50.21	66.0	35.55	1.32476	82.49	54.44
62.1	33.56	1.30118	81.02	50.31	66.1	35.60	1.32538	82.53	54.55
62.2	33.61	1.30178	81.05	50.41	66.2	35.65	1.32599	82.67	54.65
62.3	33.67	1.30238	81.09	50.52	66.3	35.70	1.32660	82.60	54.76
62.4	33.72	1.30298	81.13	50.63	66.4	35.75	1.32722	82.64	54.87
62.5	33.77	1.30358	81.16	50.73	66.5	35.80	1.32783	82.68	54.98
62.6	33.82	1.30418	81.20	50.83	66.6	35.85	1.32844	82.72	55.09
62.7	33.87	1.30477	81.24	50.94	66.7	35.90	1.32906	82.75	55.19
62.8	33.92	1.30537	81.28	51.04	66.8	35.95	1.32967	82.79	55.30
62.9	33.97	1.30597	81.32	51.15	66.9	36.00	1.33029	82.83	55.41

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
67.0	36.05	1.33090	82.87	55.52	71.0	38.06	1.35585	84.42	59.94
67.1	36.10	1.33152	82.91	55.63	71.1	38.11	1.35648	84.46	60.05
67.2	36.15	1.33214	82.95	55.74	71.2	38.16	1.35711	84.50	60.15
67.3	36.20	1.33275	82.98	55.85	71.3	38.21	1.35775	84.54	60.28
67.4	36.25	1.33337	83.02	55.96	71.4	38.26	1.35838	84.58	60.39
67.5	36.30	1.33399	83.06	56.07	71.5	38.30	1.35901	84.62	60.50
67.6	36.35	1.33460	83.10	56.18	71.6	38.35	1.35964	84.66	60.62
67.7	36.40	1.33523	83.14	56.29	71.7	38.40	1.36028	84.70	60.73
67.8	36.45	1.33584	83.18	56.40	71.8	38.45	1.36091	84.74	60.84
67.9	36.50	1.33646	83.22	56.51	71.9	38.50	1.36155	84.78	60.96
68.0	36.55	1.33708	83.25	56.61	72.0	38.55	1.36218	84.82	61.07
68.1	36.61	1.33770	83.29	56.72	72.1	38.60	1.36282	84.85	61.18
68.2	36.66	1.33832	83.33	56.83	72.2	38.65	1.36346	84.89	61.29
68.3	36.71	1.33894	83.37	56.94	72.3	38.70	1.36409	84.93	61.40
68.4	36.76	1.33957	83.41	57.05	72.4	38.75	1.36473	84.97	61.52
68.5	36.81	1.34019	83.45	57.16	72.5	38.80	1.36536	85.02	61.64
68.6	36.86	1.34081	83.49	57.27	72.6	38.85	1.36600	85.06	61.75
68.7	36.91	1.34143	83.52	57.38	72.7	38.90	1.36664	85.10	61.87
68.8	36.96	1.34205	83.56	57.49	72.8	38.95	1.36728	85.14	61.98
68.9	37.01	1.34268	83.60	57.60	72.9	39.00	1.36792	85.18	62.10
69.0	37.06	1.34330	83.64	57.71	73.0	39.05	1.36856	85.22	62.21
69.1	37.11	1.34392	83.68	57.82	73.1	39.10	1.36919	85.26	62.33
69.2	37.16	1.34455	83.72	57.93	73.2	39.15	1.36983	85.29	62.43
69.3	37.21	1.34517	83.76	58.05	73.3	39.20	1.37047	85.33	62.55
69.4	37.26	1.34580	83.80	58.16	73.4	39.25	1.37111	85.37	62.66
69.5	37.31	1.34642	83.84	58.27	73.5	39.30	1.37176	85.42	62.78
69.6	37.36	1.34705	83.88	58.38	73.6	39.35	1.37240	85.45	62.89
69.7	37.41	1.34768	83.91	58.49	73.7	39.39	1.37304	85.49	63.01
69.8	37.46	1.34830	83.95	58.60	73.8	39.44	1.37368	85.53	63.12
69.9	37.51	1.34893	83.99	58.71	73.9	39.49	1.37432	85.57	63.24
70.0	37.56	1.34956	84.03	58.82	74.0	39.54	1.37496	85.61	63.35
70.1	37.61	1.35019	84.07	58.93	74.1	39.59	1.37561	85.66	63.47
70.2	37.66	1.35081	84.11	59.05	74.2	39.64	1.37625	85.70	63.59
70.3	37.71	1.35144	84.15	59.16	74.3	39.69	1.37689	85.74	63.70
70.4	37.76	1.35207	84.19	59.27	74.4	39.74	1.37754	85.78	63.82
70.5	37.81	1.35270	84.23	59.38	74.5	39.79	1.37818	85.82	63.94
70.6	37.86	1.35333	84.26	59.49	74.6	39.84	1.37883	85.86	64.05
70.7	37.91	1.35396	84.30	59.60	74.7	39.89	1.37947	85.90	64.17
70.8	37.96	1.35459	84.34	59.71	74.8	39.94	1.38012	85.94	64.28
70.9	38.01	1.35522	84.38	59.83	74.9	39.99	1.38076	85.98	64.40

BRIX, BAUMÉ, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
75.0	40.03	1.38141	86.02	64.52	79.0	41.99	1.40758	87.65	69.24
75.1	40.08	1.38206	86.06	64.63	79.1	42.03	1.40824	87.69	69.36
75.2	40.13	1.38270	86.10	64.75	79.2	42.08	1.40890	87.73	69.48
75.3	40.18	1.38335	86.14	64.86	79.3	42.13	1.40956	87.77	69.60
75.4	40.23	1.38400	86.18	64.98	79.4	42.18	1.41023	87.81	69.72
75.5	40.28	1.38465	86.22	65.10	79.5	42.23	1.41089	87.85	69.84
75.6	40.33	1.38530	86.26	65.21	79.6	42.28	1.41155	87.89	69.96
75.7	40.38	1.38595	86.30	65.33	79.7	42.32	1.41222	87.93	70.08
75.8	40.43	1.38650	86.34	65.45	79.8	42.37	1.41288	87.98	70.21
75.9	40.48	1.38725	86.38	65.56	79.9	42.42	1.41355	88.02	70.33
76.0	40.53	1.38790	86.42	65.68	80.0	42.47	1.41421	88.06	70.45
76.1	40.57	1.38855	86.46	65.80	80.1	42.52	1.41488	88.10	70.57
76.2	40.62	1.38920	86.50	65.91	80.2	42.57	1.41554	88.14	70.69
76.3	40.67	1.38935	86.54	66.03	80.3	42.61	1.41621	88.19	70.82
76.4	40.72	1.39050	86.58	66.15	80.4	42.66	1.41688	88.23	70.94
76.5	40.77	1.39115	86.62	66.26	80.5	42.71	1.41754	88.27	71.06
76.6	40.82	1.39180	86.66	66.38	80.6	42.76	1.41821	88.31	71.18
76.7	40.87	1.39246	86.70	66.50	80.7	42.81	1.41888	88.35	71.30
76.8	40.92	1.39311	86.75	66.62	80.8	42.85	1.41955	88.39	71.42
76.9	40.97	1.39376	86.79	66.74	80.9	42.90	1.42022	88.43	71.54
77.0	41.01	1.39442	86.83	66.86	81.0	42.95	1.42088	88.48	71.67
77.1	41.06	1.39507	86.87	66.98	81.1	43.00	1.42155	88.52	71.79
77.2	41.11	1.39573	86.91	67.09	81.2	43.05	1.42222	88.56	71.91
77.3	41.16	1.39638	86.95	67.21	81.3	43.10	1.42289	88.60	72.03
77.4	41.21	1.39704	86.99	67.33	81.4	43.14	1.42356	88.64	72.15
77.5	41.26	1.39769	87.03	67.45	81.5	43.19	1.42434	88.68	72.27
77.6	41.31	1.39835	87.07	67.57	81.6	43.24	1.42490	88.73	72.40
77.7	41.36	1.39901	87.11	67.68	81.7	43.29	1.42558	88.77	72.53
77.8	41.40	1.39966	87.15	67.80	81.8	43.33	1.42625	88.81	72.65
77.9	41.45	1.40032	87.19	67.92	81.9	43.38	1.42692	88.85	72.77
78.0	41.50	1.40098	87.24	68.05	82.0	43.43	1.42759	88.89	72.89
78.1	41.55	1.40164	87.28	68.17	82.1	43.48	1.42827	88.94	73.02
78.2	41.60	1.40230	87.32	68.28	82.2	43.53	1.42894	88.98	73.14
78.3	41.65	1.40295	87.36	68.40	82.3	43.57	1.42961	89.02	73.26
78.4	41.70	1.40361	87.40	68.52	82.4	43.62	1.43029	89.06	73.39
78.5	41.74	1.40427	87.44	68.64	82.5	43.67	1.43096	89.10	73.51
78.6	41.79	1.40493	87.48	68.76	82.6	43.72	1.43164	89.15	73.64
78.7	41.84	1.40559	87.52	68.89	82.7	43.77	1.43231	89.19	73.76
78.8	41.89	1.40625	87.56	69.00	82.8	43.81	1.43298	89.23	73.88
78.9	41.94	1.40691	87.61	69.12	82.9	43.86	1.43366	89.27	74.00

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
83.0	43.91	1.43434	89.31	74.13	87.0	45.80	1.46170	91.02	79.19
83.1	43.96	1.43502	89.36	74.26	87.1	45.85	1.46239	91.06	79.31
83.2	44.00	1.43569	89.40	74.38	87.2	45.89	1.46308	91.11	79.45
83.3	44.05	1.43637	89.44	74.50	87.3	45.94	1.46377	91.15	79.57
83.4	44.10	1.43705	89.48	74.63	87.4	45.99	1.46446	91.19	79.70
83.5	44.15	1.43773	89.53	74.76	87.5	46.03	1.46516	91.24	79.84
83.6	44.19	1.43841	89.57	74.88	87.6	46.08	1.46585	91.28	79.96
83.7	44.24	1.43908	89.61	75.00	87.7	46.13	1.46654	91.32	80.09
83.8	44.29	1.43976	89.65	75.13	87.8	46.17	1.46724	91.36	80.21
83.9	44.34	1.44044	89.69	75.25	87.9	46.22	1.46793	91.41	80.35
84.0	44.38	1.44112	89.74	75.38	88.0	46.27	1.46862	91.45	80.48
84.1	44.43	1.44180	89.78	75.50	88.1	46.31	1.46932	91.49	80.60
84.2	44.48	1.44249	89.82	75.63	88.2	46.36	1.47002	91.54	80.74
84.3	44.53	1.44317	89.86	75.75	88.3	46.41	1.47071	91.58	80.87
84.4	44.57	1.44385	89.91	75.88	88.4	46.45	1.47141	91.62	80.99
84.5	44.62	1.44453	89.95	76.01	88.5	46.50	1.47210	91.67	81.13
84.6	44.67	1.44521	89.99	76.13	88.6	46.55	1.47280	91.71	81.26
84.7	44.72	1.44590	90.04	76.26	88.7	46.59	1.47350	91.75	81.38
84.8	44.76	1.44658	90.08	76.39	88.8	46.64	1.47420	91.80	81.52
84.9	44.81	1.44726	90.12	76.51	88.9	46.69	1.47489	91.84	81.65
85.0	44.86	1.44794	90.16	76.64	89.0	46.73	1.47559	91.89	81.78
85.1	44.91	1.44863	90.21	76.77	89.1	46.78	1.47629	91.92	81.90
85.2	44.95	1.44931	90.25	76.89	89.2	46.83	1.47699	91.97	82.04
85.3	45.00	1.45000	90.29	77.02	89.3	46.87	1.47769	92.02	82.17
85.4	45.05	1.45068	90.33	77.14	89.4	46.92	1.47839	92.06	82.30
85.5	45.09	1.45137	90.38	77.27	89.5	46.97	1.47909	92.10	82.43
85.6	45.14	1.45205	90.42	77.40	89.6	47.01	1.47979	92.15	82.57
85.7	45.19	1.45274	90.46	77.52	89.7	47.06	1.48049	92.19	82.69
85.8	45.24	1.45343	90.50	77.65	89.8	47.11	1.48119	92.23	82.82
85.9	45.28	1.45411	90.55	77.78	89.9	47.15	1.48189	92.28	82.96
86.0	45.33	1.45480	90.59	77.91	90.0	47.20	1.48259	92.32	83.09
86.1	45.38	1.45549	90.63	78.03	90.1	47.24	1.48330	92.37	83.23
86.2	45.42	1.45618	90.68	78.17	90.2	47.29	1.48400	92.41	83.35
86.3	45.47	1.45686	90.72	78.29	90.3	47.34	1.48470	92.45	83.48
86.4	45.52	1.45755	90.76	78.42	90.4	47.38	1.48540	92.49	83.71
86.5	45.57	1.45824	90.80	78.54	90.5	47.43	1.48611	92.54	83.74
86.6	45.61	1.45893	90.85	78.68	90.6	47.48	1.48681	92.58	83.88
86.7	45.66	1.45962	90.89	78.80	90.7	47.52	1.48752	92.63	84.01
86.8	45.71	1.46031	90.93	78.93	90.8	47.57	1.48822	92.67	84.14
86.9	45.75	1.46100	90.97	79.05	90.9	47.61	1.48893	92.72	84.28

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
91.0	47.66	1.48963	92.76	84.41	95.0	49.49	1.51814	94.54	89.81
91.1	47.71	1.49034	92.81	84.55	95.1	49.53	1.51886	94.58	89.95
91.2	47.75	1.49104	92.85	84.68	95.2	49.58	1.51958	94.63	90.08
91.3	47.80	1.49175	92.89	84.82	95.3	49.62	1.52030	94.67	90.22
91.4	47.84	1.49246	92.94	84.95	95.4	49.67	1.52102	94.72	90.36
91.5	47.89	1.49316	92.98	85.09	95.5	49.71	1.52174	94.76	90.50
91.6	47.94	1.49387	93.02	85.22	95.6	49.76	1.52246	94.81	90.64
91.7	47.98	1.49458	93.07	85.35	95.7	49.80	1.52318	94.85	90.77
91.8	48.03	1.49529	93.11	85.47	95.8	49.85	1.52390	94.90	90.91
91.9	48.08	1.49600	93.15	85.60	95.9	49.90	1.52463	94.94	91.04
92.0	48.12	1.49671	93.20	85.74	96.0	49.94	1.52535	94.99	91.19
92.1	48.17	1.49741	93.24	85.87	96.1	49.98	1.52607	95.03	91.32
92.2	48.21	1.49812	93.29	86.01	96.2	50.03	1.52680	95.08	91.46
92.3	48.26	1.49883	93.33	86.14	96.3	50.08	1.52752	95.12	91.60
92.4	48.30	1.49954	93.37	86.27	96.4	50.12	1.52824	95.17	91.74
92.5	48.35	1.50026	93.42	86.41	96.5	50.16	1.52897	95.21	91.88
92.6	48.40	1.50097	93.47	86.55	96.6	50.21	1.52969	95.26	92.02
92.7	48.44	1.50168	93.51	86.68	96.7	50.25	1.53042	95.30	92.16
92.8	48.49	1.50239	93.55	86.82	96.8	50.30	1.53114	95.35	92.30
92.9	48.53	1.50310	93.60	86.95	96.9	50.34	1.53187	95.39	92.43
93.0	48.58	1.50381	93.64	87.09	97.0	50.39	1.53260	95.44	92.57
93.1	48.62	1.50453	93.69	87.23	97.1	50.43	1.53332	95.48	92.71
93.2	48.67	1.50524	93.73	87.36	97.2	50.48	1.53405	95.53	92.86
93.3	48.72	1.50595	93.77	87.49	97.3	50.52	1.53478	95.57	93.00
93.4	48.76	1.50667	93.82	87.63	97.4	50.57	1.53551	95.62	93.13
93.5	48.81	1.50738	93.87	87.77	97.5	50.61	1.53623	95.66	93.27
93.6	48.85	1.50810	93.91	87.90	97.6	50.66	1.53696	95.71	93.41
93.7	48.90	1.50881	93.96	88.04	97.7	50.70	1.53769	95.75	93.55
93.8	48.94	1.50952	94.00	88.17	97.8	50.75	1.53842	95.80	93.69
93.9	48.99	1.51024	94.04	88.30	97.9	50.79	1.53915	95.85	93.83
94.0	49.03	1.51096	94.09	88.44	98.0	50.84	1.53988	95.89	93.97
94.1	49.08	1.51167	94.13	88.58	98.1	50.88	1.54061	95.94	94.12
94.2	49.12	1.51239	94.18	88.72	98.2	50.93	1.54134	95.98	94.26
94.3	49.17	1.51311	94.22	88.85	98.3	50.97	1.54207	96.03	94.40
94.4	49.22	1.51382	94.27	88.99	98.4	51.02	1.54280	96.08	94.54
94.5	49.26	1.51454	94.31	89.12	98.5	51.06	1.54353	96.12	94.68
94.6	49.31	1.51526	94.36	89.26	98.6	51.10	1.54426	96.17	94.82
94.7	49.35	1.51598	94.40	89.40	98.7	51.15	1.54499	96.22	94.97
94.8	49.40	1.51670	94.45	89.53	98.8	51.19	1.54573	96.26	95.11
94.9	49.44	1.51742	94.49	89.67	98.9	51.24	1.54646	96.30	95.25

Brix, Baumé, and Specific Gravity of Sugar Solutions—*Continued*

Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.	Degrees Brix or Per Cent Sugar by Weight.	Degrees Baumé, Modulus 145.	Specific Gravity at 20/20° C.	Pounds per Cubic Foot.	Pounds Dry Substance per Cubic Foot.
99.0	51.28	1.54719	96.35	95.39	99.5	51.50	1.55087	96.58	96.10
99.1	51.33	1.54793	96.40	95.53	99.6	51.55	1.55160	96.62	96.24
99.2	51.37	1.54866	96.44	95.67	99.7	51.59	1.55234	96.66	96.38
99.3	51.42	1.54939	96.48	95.81	99.8	51.64	1.55307	96.71	96.52
99.4	51.46	1.55013	96.53	95.95	99.9	51.68	1.55381	96.76	96.66
					100.0	51.23	1.55454	96.80	96.80

GRANULATED FACTORS

If we take x parts of sugar out of a fillmass of a Purity $=P_1$, the proportion of the sugar to the dry substance of the remaining syrup will be:

$$\frac{P_1-x}{100-x}.$$

If the purity of the resulting syrups be P_2, we will have the formula:

$$\frac{P-x}{100-x}=\frac{P_2}{100} \text{ or } x=\frac{100(P_1-P_2)}{100-P_2}$$

$=$per cent of sugar taken out of 100 parts of dry substance.

$S=$per cent of sugar on original sugar $=100\frac{x}{P_1}$. The purity of the final molasses varies with different campaigns, in different States, with different soil and climatic conditions. The non-sugars of the beets and molasses in the Intermountain States are different from the non-sugars of the beets and molasses in California. While there is a considerable amount of raffinose, or so-called raffinose, for instance in the Intermountain States and Michigan, there is none in California. The purities of the final molasses in the Intermountain States vary from 57 to 63, while in California purities of 54 and less are often reached, which shows the difference between the non-sugars in different molasses.

When it comes to calculations of prospective extractions, however, it is the established practice to figure the purity of the final molasses at 60; and for that reason the following tables are given for extractions from juices of different purities to a purity of 60 in the final molasses.

GRANULATED FACTORS.

Percentage of Available Granulated on Total Solids of Sugar Solutions.

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
60	....	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	60
61	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	61
62	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.25	62
63	7.5	7.75	8.0	8.25	8.5	8.75	9.0	9.25	9.5	9.75	63
64	0.0	10.25	10.5	10.75	11.0	11.25	11.5	11.75	12.0	12.25	64
65	12.5	12.75	13.0	13.25	13.5	13.75	14.0	14.25	14.5	14.75	65
66	15.0	15.25	15.5	16.75	16.0	16.25	16.5	16.75	17.0	17.25	66
67	17.5	17.75	18.0	18.25	18.5	18.75	19.0	19.25	19.5	19.75	67
68	20.0	20.25	20.5	20.75	21.0	21.25	21.5	21.75	22.0	22.25	68
69	22.5	22.75	23.0	23.25	23.5	23.75	24.0	24.25	24.5	24.75	69
70	25.0	25.25	25.5	25.75	26.0	26.25	26.5	26.75	27.0	27.25	70
71	27.5	27.75	28.0	28.25	28.5	28.75	29.0	29.25	29.5	29.75	71
72	30.0	30.25	30.5	30.75	31.0	31.25	31.5	31.75	32.0	32.25	72
73	32.5	32.75	33.0	33.25	33.5	33.75	34.0	34.25	34.5	34.75	73
74	35.0	35.25	35.5	35.75	36.0	36.25	36.5	36.75	37.0	37.25	74
75	37.5	37.75	38.0	38.25	38.5	38.75	39.0	39.25	39.5	39.75	75
76	40.0	40.25	40.5	40.75	41.0	41.25	41.5	41.75	42.0	42.25	76
77	42.5	42.75	43.0	43.25	43.5	43.75	44.0	44.25	44.5	44.75	77
78	45.0	45.25	45.5	45.75	46.0	46.25	46.5	46.75	47.0	47.25	78
79	47.5	47.75	48.0	48.25	48.5	48.75	49.0	49.25	49.5	49.75	79
80	50.5	50.25	50.5	50.75	51.0	51.25	51.5	51.75	52.0	52.25	80
81	52.5	52.75	53.0	53.25	53.5	53.75	54.0	54.25	54.5	54.75	81
82	55.0	55.25	55.5	55.75	56.0	56.25	56.5	56.75	57.0	57.25	82
83	57.5	57.75	58.0	58.25	58.5	58.75	59.0	59.25	59.5	59.75	83
84	60.0	60.25	60.5	60.75	61.0	61.25	61.5	61.75	62.0	62.25	84
85	62.5	62.75	63.0	63.25	63.5	63.75	64.0	64.25	64.5	64.75	85
86	65.0	65.25	65.5	65.75	66.0	66.25	66.5	66.75	67.0	67.25	86
87	67.5	67.75	68.0	68.25	68.5	68.75	69.0	69.25	69.5	69.75	87
88	70.0	70.25	70.5	70.75	71.0	71.25	71.5	71.75	72.0	72.25	88
89	72.5	72.75	73.0	73.25	73.5	73.75	74.0	74.25	74.5	74.75	89
90	75.0	75.25	75.5	75.75	76.0	76.25	76.5	76.75	77.0	77.25	90
91	77.5	77.75	78.0	78.25	78.5	78.75	79.0	79.25	79.5	79.75	91
92	80.0	80.25	80.5	80.75	81.0	81.25	81.5	81.75	82.0	82.25	92
93	82.5	82.75	83.0	83.25	83.5	83.75	84.0	84.25	84.5	84.75	93
94	85.0	85.25	85.5	85.75	86.0	86.25	86.5	86.75	87.0	87.25	94
95	87.5	87.75	88.0	88.25	88.5	88.75	89.0	89.25	89.5	89.75	95
96	90.0	90.25	90.5	90.75	91.0	91.25	91.5	91.75	92.0	92.25	96
97	92.5	92.75	93.0	93.25	93.5	93.75	94.0	94.25	94.5	94.75	97
98	95.0	95.25	95.5	95.75	96.0	96.25	96.5	96.75	97.0	97.25	98
99	97.5	97.75	98.0	98.25	98.5	98.75	99.0	99.25	99.5	99.75	99
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	

PERCENTAGE OF AVAILABLE GRANULATED ON TOTAL SUGAR OF SUGAR SOLUTIONS—MOLASSES PURITY OF 60.

Purity.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
60	.....	0.42	0.83	1.25	1.66	2.07	2.48	2.88	3.29	3.69	60
61	4.10	4.50	4.90	5.30	5.70	6.10	6.49	6.89	7.28	7.67	61
62	8.06	8.45	8.84	9.23	9.62	10.00	10.38	10.77	11.15	11.53	62
63	11.90	12.28	12.66	13.03	13.41	13.78	14.15	14.52	14.89	15.26	63
64	15.62	15.99	16.36	16.72	17.08	17.44	17.80	18.16	18.52	18.88	64
65	19.23	19.59	19.94	20.29	20.64	20.99	21.34	21.69	22.04	22.38	65
66	22.73	23.07	23.41	23.76	24.10	24.44	24.77	25.11	25.45	25.79	66
67	26.12	26.45	26.79	27.12	27.45	27.78	28.11	28.43	28.76	29.09	67
68	29.41	29.74	30.06	30.38	30.70	31.02	31.34	31.66	31.98	32 29	68
69	32.61	32.92	33.24	33.55	33.86	34.17	34.48	34.79	35.10	35.41	69
70	35.71	36.02	36.32	36.63	36.93	37.23	37.54	37.84	38.14	38.43	70
71	38.73	39.03	39.33	39.62	39.92	40.21	40.50	40.79	41.09	41.38	71
72	41.67	41.96	42.24	42.53	42.82	43.10	43.39	43.67	43.96	44.24	72
73	44.52	44.80	45.08	45.36	45.64	45.92	46.20	46.47	46.75	47.02	73
74	47.30	47.57	47.84	48.12	48.39	48.66	48.93	49.20	49.47	49.73	74
75	50.00	50.27	50.53	50.80	51.06	51.32	51.59	51.85	52.11	52.37	75
76	52.63	52.89	53.15	53.41	53.66	53.92	54.18	54.43	54.69	54.94	76
77	55.19	55.45	55.70	55.95	56.20	56.45	56.70	56.95	57.20	57.45	77
78	57.69	57.94	58.18	58.43	58.67	58.92	59.16	59.40	59.64	59.89	78
79	60.13	60.37	60.61	60.85	61.08	61.32	61.56	61.79	62.03	62.27	79
80	62.50	62.73	62.97	63.20	63.43	63.66	63.90	64.13	64.36	64.59	80
81	64.81	65.04	65.27	65.50	65.72	65.95	66.18	66.40	66.63	66.85	81
82	67.07	67.30	67.52	67.74	67.96	68.18	68.40	68.62	68.84	69.06	82
83	69.28	69.49	69.71	69.93	70.14	70.36	70.57	70.79	61.00	72.11	83
84	71.43	71.64	71.85	72.06	72.27	72.49	72.70	72.90	73.11	73.32	84
85	73.53	73.74	73.94	74.15	74.36	84.56	74.77	74.97	75.17	75.38	85
86	75.58	75.76	75.99	76.19	76.39	76.59	76.79	76.99	77.19	77.39	86
87	77.59	77.78	77.98	78.18	78.38	78.57	78.77	78.96	79.16	79.35	87
88	79.55	79.74	79.93	80.12	80.32	80.51	80.70	80.89	81.08	81.27	88
89	81.46	81.65	81.84	82.03	82.21	82.40	82.59	82.78	82.96	83.15	89
90	83.33	83.52	83.70	83.89	84.07	84.25	84.44	84.62	84.80	84.98	90
91	85.16	85.35	85.53	85.71	85.89	86.07	86.24	86.42	86.60	86.78	91
92	86.96	87.13	87.31	87.49	87.66	87.84	88.01	88.19	88.36	88.54	92
93	88.71	88.88	89.06	89.23	89.40	89.57	89.74	89.91	90.09	90.26	93
94	90.43	90.60	90.76	90.93	91.10	91.27	91.44	91.61	91.77	91.94	94
95	92.11	92.27	92.44	92.60	92.77	92.93	93.10	93.26	93.42	93.59	95
96	93.75	93.91	94.07	94.24	94.40	94.56	94.72	94.88	95.04	95.20	96
97	95.36	95.52	95.68	95.84	96.00	96.15	96.31	96.47	96.63	96.78	97
98	96.94	97.09	97.25	97.41	97.56	97.72	97.87	98.02	98.18	98.33	98
99	98.48	98.64	98.79	98.94	99.09	99.25	99.40	99.55	99.70	99.85	99
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	

TEMPERATURE CORRECTION TABLE FOR BRIX HYDROMETERS (STANDARD TEMPERATURE 20° C.)

(Figured to the nearest .05° Brix)

Temperature ° C.	Degrees Brix											Temperature ° C.
	0	5	10	15	20	25	30	40	50	60	70	
	Subtract from the Observed Reading											
15	.20	.20	.25	.25	.30	.30	.30	.35	.35	.40	.40	15
16	.15	.20	.20	.20	.25	.25	.25	.30	.30	.30	.30	16
17	.15	.15	.15	.15	.20	.20	.20	.20	.20	.25	.25	17
18	.10	.10	.10	.10	.10	.15	.15	.15	.15	.15	.15	18
19	.05	.05	.05	.05	.05	.05	.05	.05	.10	.10	.10	19
	Add to the Observed Reading											
21	.05	.05	.05	.05	.05	.05	.05	.05	.10	.10	.10	21
22	.10	.10	.10	.10	.10	.15	.15	.15	.15	.15	.15	22
23	.15	.15	.15	.15	.20	.20	.20	.20	.25	.25	.25	23
24	.20	.20	.25	.25	.25	.25	.30	.30	.30	.30	.30	24
25	.25	.30	.30	.30	.30	.35	.35	.40	.40	.40	.40	25
26	.35	.35	.35	.35	.40	.40	.40	.45	.45	.50	.50	26
27	.40	.40	.40	.45	.45	.50	.50	.55	.55	.55	.55	27
28	.45	.45	.50	.50	.55	.55	.60	.60	.65	.65	.65	28
29	.55	.55	.55	.60	.60	.65	.65	.70	.70	.70	.70	29
30	.60	.60	.65	.65	.70	.70	.75	.80	.80	.80	.80	30
35	1.00	1.00	1.00	1.05	1.10	1.15	1.15	1.20	1.20	1.25	1.20	35
40	1.40	1.45	1.45	1.50	1.55	1.55	1.60	1.65	1.65	1.65	1.65	40
45	1.90	1.95	1.95	2.00	2.05	2.05	2.05	2.10	2.10	2.10	2.10	45
50	2.45	2.50	2.50	2.55	2.55	2.55	2.60	2.60	2.60	2.55	2.50	50
60	3.70	3.70	3.75	3.75	3.70	3.70	3.65	3.60	3.55	3.50	3.45	60
	0	5	10	15	20	25	30	40	50	60	70	

See Table 11, Bureau of Standards Circular 44, 2d ed., for complete table figured to the nearest .01° Brix.

CONVERSION TABLES

METRIC SYSTEM TO U. S. MEASUREMENTS

Conversion of Length

1 meter = 1 m. = 10 decimeters = 10 dm. = 100 centimeters = 100 cm. = 1000 millimeters = 1000 mm.
1 m. = 39.37 inches (39.37″) = 3.281 feet (3.281′)
1 cm. = .3937″
1 inch = 1″ = 2.54 cm.
1 foot = 1′ = 30.48 cm.

Conversion of Areas

1 sq. cm. = 0.1550 sq. in.
1 sq. in. = 6.452 sq. cm.
1 sq. m. = 10.76 sq. ft.
1 sq. ft = 0.0929 sq. m.

Conversion of Volumes or Cubic Measures

1 cu. cm. = 0.06102 cu. in.
1 cu. in. = 16.39 cu. cm.
1 cu. m. = 1000 cu. dm. = 1000l. = 35.31 cu. ft. = 264.15 gallons.
1 cu. ft. = .02832 cu. m. = 28.32l
1 gallon = 3.785 l.

Conversion of Volumes to Masses

The weight of one cubic centimeter of water at 4° C. = 1 gram.
1 liter (1 l.) = 1000 gr. = 1 kilogram (1 kg.)
1 cubic meter = 1 cb.m. = 1000 kg. = 1 metric ton.
1 metric ton = .984 long ton (of 2240 lbs.) = 1.102 short tons (of 2000 lbs.)
1 kg. = 1000 gr. = 2.205 pounds (lbs.)
1 lb. = 453.6 gr. = 0.4536 kg.
1 short ton (2000 lbs.) = .907 metric ton.
1 long ton (2240 lbs.) = 1.016 metric tons.

Definition of Calories and B.T.U.

One Calorie is the amount of heat required to heat 1 kg. of water 1° Celsius.

One B.T.U. (British thermal unit) is the amount of heat required to heat 1 lb. of water 1° Fahrenheit.

The actual amount of heat represented by 1 calorie is therefore 3.96 times the amount of heat represented by one B.T.U. (1 kg. = 2.2 lbs. and 1° C. = 1.8° F; 2.2×1.8 = 3.96).

In speaking of the heat value of a certain coal, however, the heat value of the coal expressed in calories is based on the heat produced by one kilogram of coal, while the heat value of coal expressed in B.T.U. is based on the heat produced by one pound of coal.

The proportion of heat expressed in calories and in B.T.U. is therefore 1 : 1.8; or a coal of 6000 calories is equivalent to a coal of 6000×1.8 = 10,800 B.T.U.